6.3 FOOD-WEB EXPOSURE CHARACTERIZATION

The biota tissue sampling—fish, crab, and insect tissue—represents three potential food-web transfer routes for site-related contamination. Because these tissue samples are a component of other measurement endpoints in this risk assessment, the following sections present only results of the chemical analysis of these tissues. Their use as dietary inputs to the avian food-web model was discussed previously.

6.3.1 Fish Tissue Body Burdens

The life history of the mummichog and the habitat features in the study area indicate that many reaches offer ideal habitat for the mummichog. Their presence in nearshore shallow waters and benthic feeding habits indicate likely exposure to site-related contamination. These fish could be exposed by consuming benthic organisms that have accumulated contaminants from the sediments, direct exposure to contaminated sediment and surface water, and incidental ingestion of contaminated sediments and water. Exposure could occur year-round to all life stages since the species is not known to migrate and tolerates a wide variety of salinity and temperatures. Because their home range is limited and they do not migrate, samples of mummichog should represent localized conditions.

Results from fish tissue chemical analysis are presented in **Figures 6-19 through 6-22.** Targeted and measured detection limits are compared in **Table 6-5**; observed tissue concentration ranges are summarized in **Table 6-6.** Nine metals were detected in fish tissue samples from all locations. Variability in body burdens within an area (e.g., Upper Ferry Creek) was high, possibly reflecting the extremely heterogeneous pattern of contaminant distribution. For instance, there was an order-of-magnitude range in lead levels among the four composite samples from Upper Ferry Creek. Statistical tests of mean body burdens for Upper and Lower Ferry Creek samples versus the reference area fish (Kruskal-Wallis) indicate that mean tissue levels of cadmium, copper, lead, and zinc were significantly elevated in Upper Ferry Creek fish, while silver body burdens were significantly depressed. For cadmium, copper, and lead, tissue body burdens were significantly higher in Upper Ferry Creek fish than Lower Ferry Creek fish. Lower Ferry creek fish contained significantly higher mean levels of arsenic than reference fish. Upper Ferry Creek fish also had the highest mean levels of detected PAHs and dioxin TEQs; mean body burdens were significantly greater than either the reference fish or Lower Ferry Creek fish on either a wet-weight or lipid-weight basis. Because of problems with detection limits, tissue concentrations of PCBs were not evaluated in any detail.

6.3.2 Crab Tissue Body Burdens

Results from crab-tissue chemical analysis are presented in **Figures 6-23 through 6-24.** Table 6-5 compares targeted and measured detection limits; **Table 6-7** summarizes actual measured tissue concentrations. Eight metals were detected in crab tissues from all locations. Copper and lead levels were the most elevated, particularly in the boat club wetland sample. Copper was twice the level measured in the reference sample collected from Milford Point, while lead was 14 times higher. Copper and lead were also higher than the reference concentrations in the Upper Ferry Creek sample, but not as elevated as the boat club sample. The only other substantial difference observed in body burdens of metals was that Cd levels in the sample from Upper Ferry Creek were two orders of magnitude greater than those in the reference sample. Aroclor 1260 was also detected in crab tissue. The sample from the boat club wetland contained the highest level of PCBs, greater than 20 times the concentrations detected at the reference area. Ferry Creek samples had concentrations of PCBs two to four

times greater than the reference sample. A variety of high-molecular-weight PAHs were detected in crab samples from all stations. The highest levels occurred in the Upper Ferry Creek sample, followed by the Lower Ferry Creek sample. Dioxins and furans were also observed in all samples. The highest TCDD TEQ was in the boat club sample. Although this sample had a TCDD TEQ greater than the reference sample, most of the difference can be attributed to higher furan concentrations. The TCDD TEQ for the Upper Ferry Creek sample was about twice the reference values.

Because of the limited number of samples, statistical tests of crab body-burden data are extremely limited. Mean tissue body burdens of the three site-related samples (Upper & Lower Ferry Creek plus the boat club wetlands) were tested against the value obtained in the reference samples by Students *t*-test. Wet weight values were tested for trace elements while both wet-weight and lipid-normalized values were tested for the organics. The only detectable difference using this approach was in body burdens of chromium, mercury, and lead.

6.3.3 Insect Tissue Body Burdens

Results from insect-tissue chemical analysis are presented in **Figure 6-25**. Seven metals were detected in the insect composite samples. Targeted detection limits and measured detection limits are compared in Table 6-5. The actual tissue concentrations detected appear in **Table 6-8**. Levels of metals appear generally comparable between the two samples, except that lead was three times greater in the reference sample than in the sample collected at Ferry Creek. No chlorinated compounds were detected, and only two PAHs (phenanthrene and indeno-pyrene) were detected in each sample. The TCDD TEQ was about 60% greater in the Ferry Creek sample than the reference sample. This difference was largely due to dioxins: the dioxin contribution to the total TCDD TEQ in the Ferry Creek sample was twice that in the reference sample, while the TEQ contribution from the furans was similar in both samples.

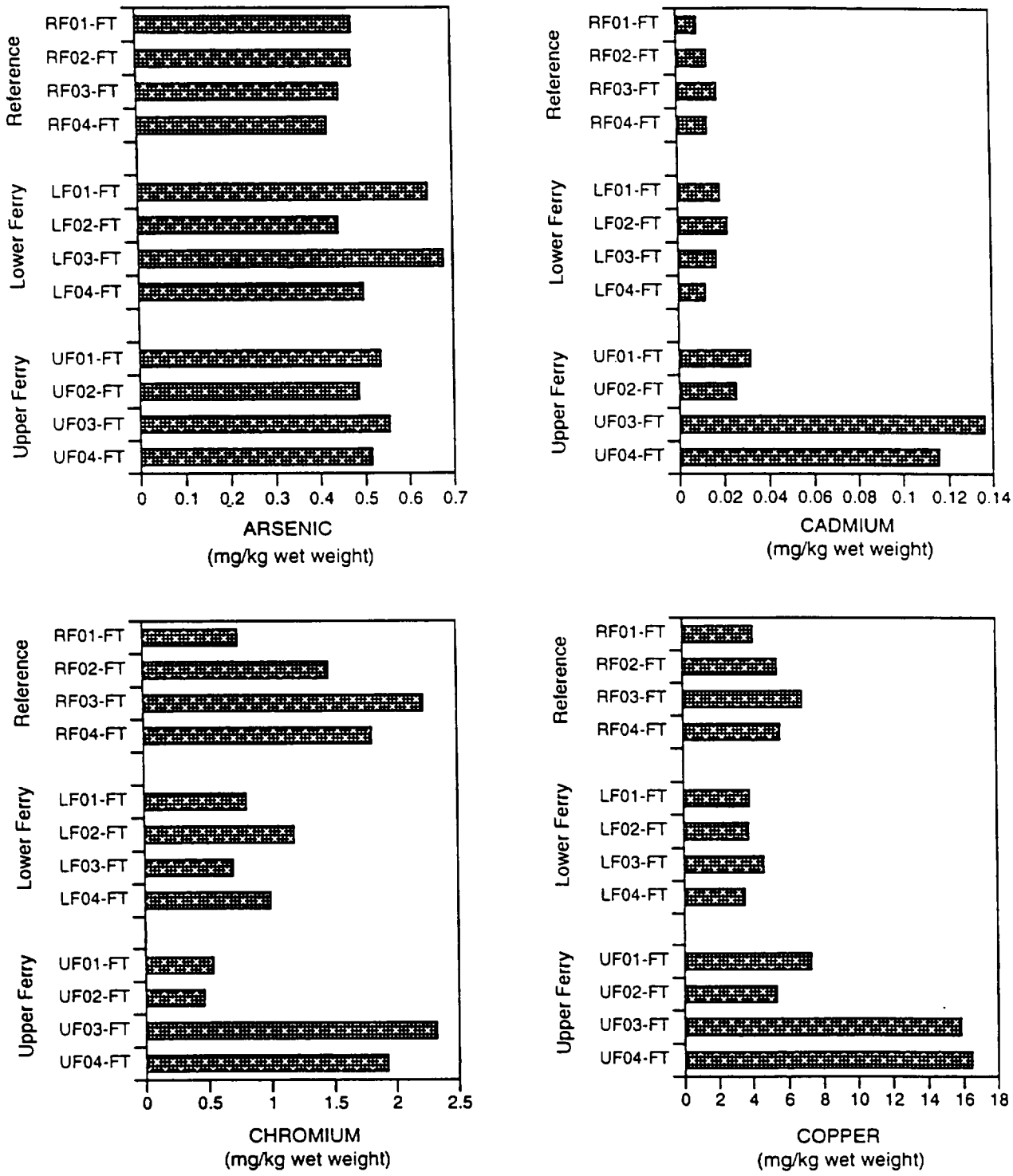

Figure 6-19. Arsenic, cadmium, chromium, and copper tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

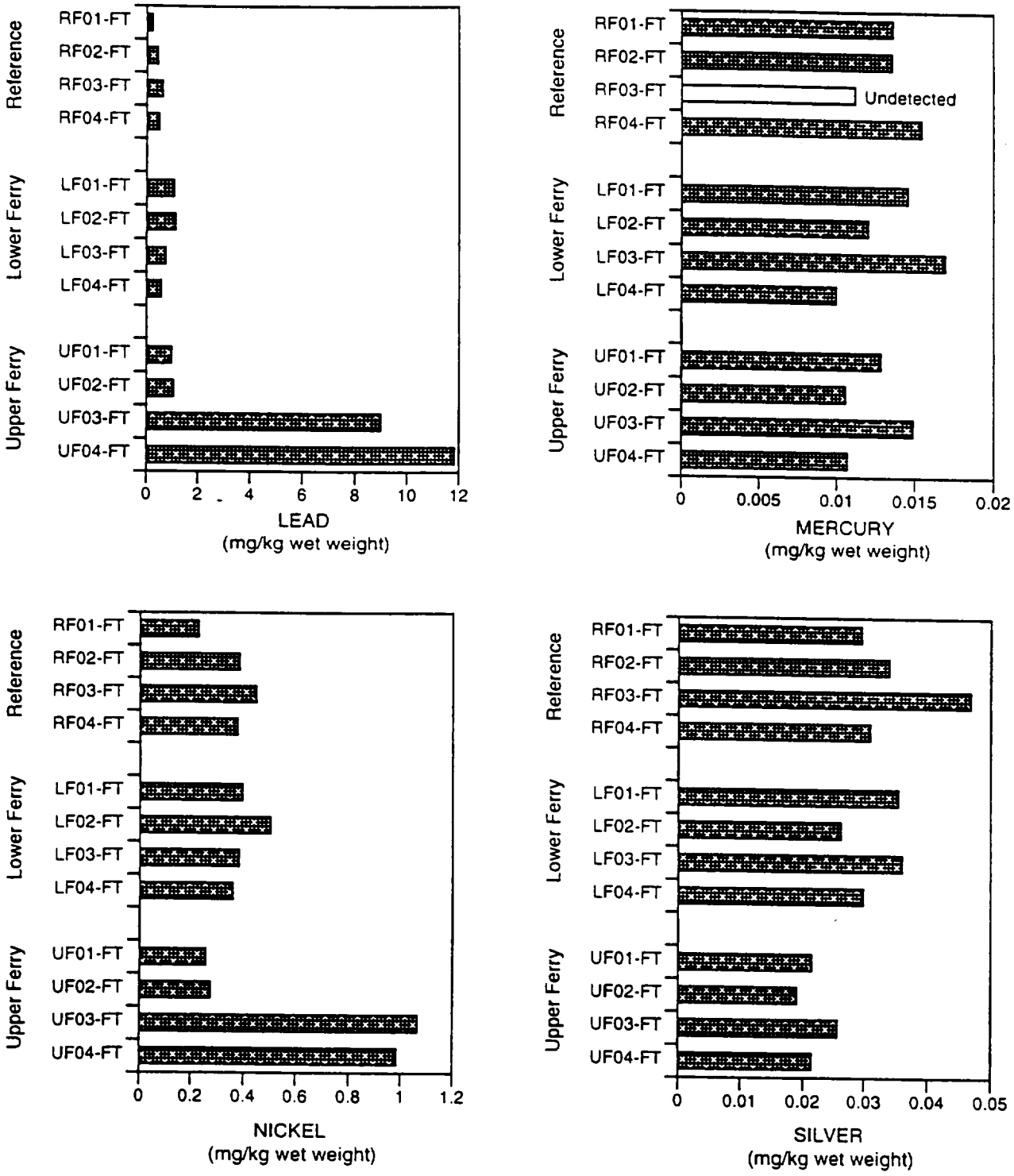

Figure 6-20. Lead, mercury, nickel, and silver tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

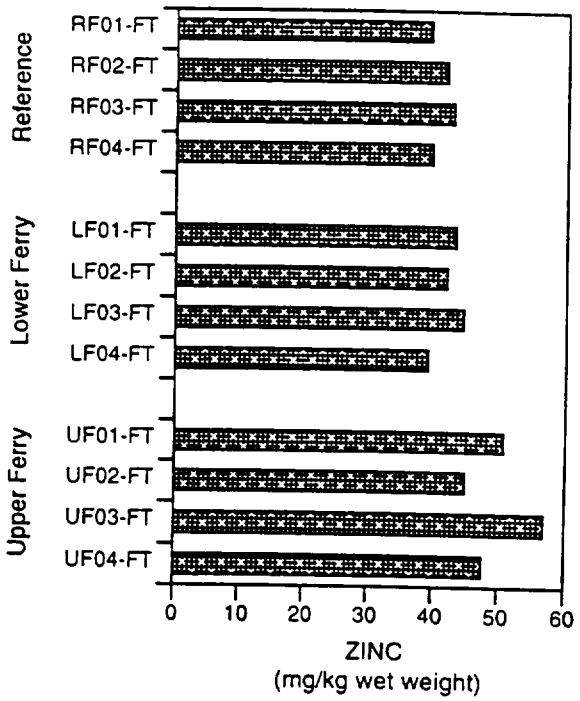

Figure 6-21. Zinc tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

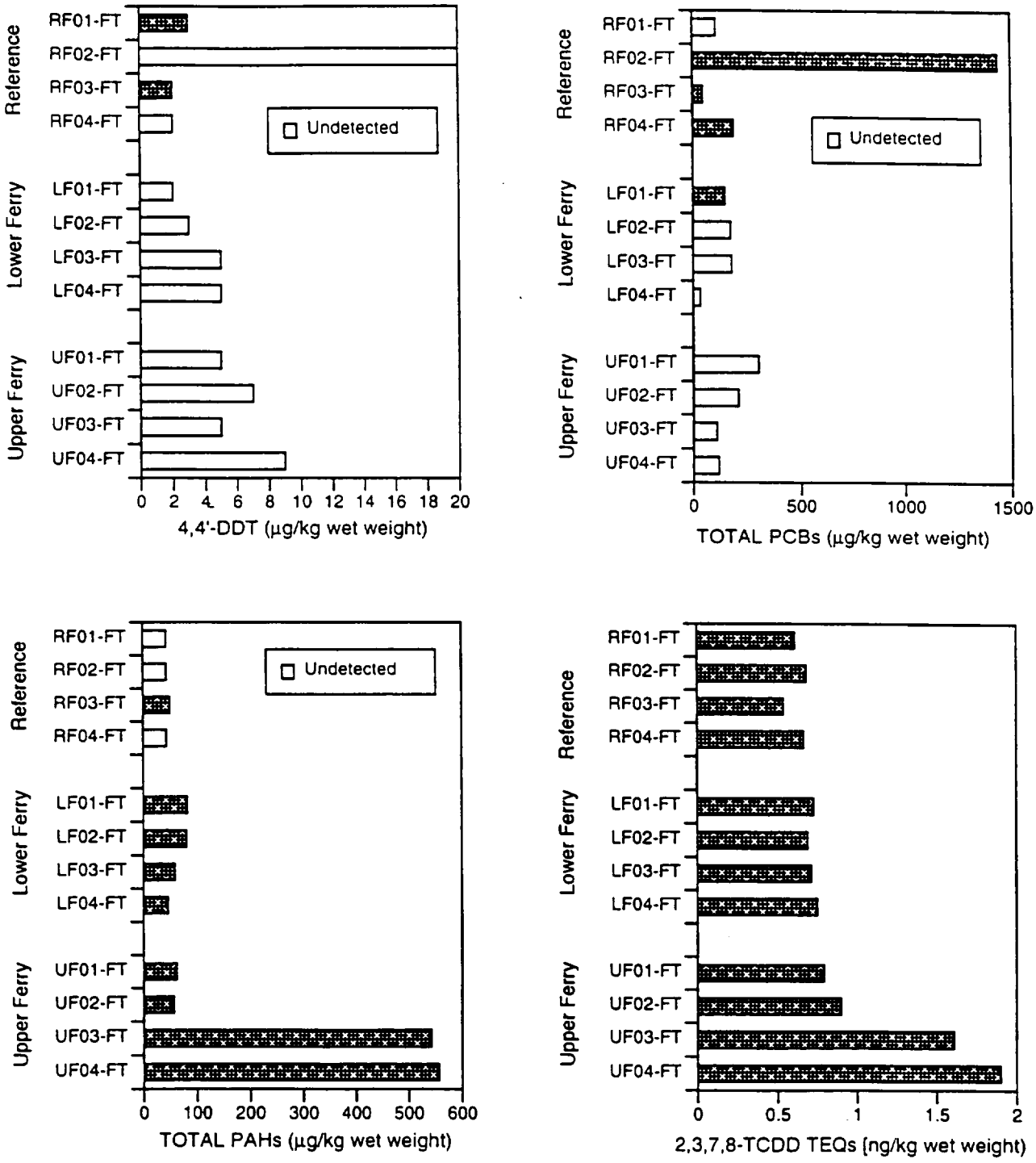

Figure 6-22. DDT, PCB, PAH and TCDD TEQ tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

Table 6-5. Comparison of targeted detection limits with measured detection limits in fish, crab, and insect tissues.

ANALYTES	DETECTION LIMITS FOR FISH TISSUE		DETECTION LIMITS FOR CRAB TISSUE		DETECTION LIMITS FOR INSECT TISSUE	
	TARGETED	MEASURED	TARGETED	MEASURED	TARGETED	MEASURED
HEMICAL PARAMETERS						
etals in µg/kg						
Arsenic	0.5	nu	0.5	nu	0.5	0.24
Cadmium	0.02	nu	0.02	nu	0.5	0.24
Chromium	0.2	nu	0.2	nu	0.2	nu
Copper	0.05	nu	0.05	nu	0.05	nu
Lead	1.1	nu	55	nu	3.5	nu
Mercury	3	nu	592	0.02	37	0.02
Nickel	0.2	nu	0.2	nu	0.5	nu
Silver	0.02	nu	0.02	nu	0.02	nu
Zinc	0.5	nu	0.5	nu	0.5	nu
PAHs in µg/kg						
Naphthalene	na	5.0	10093	5.0	634	20
2-Methylnaphthalene	na	5.0	259	nr	16	nr
Acenapnthylene	na	5.0	259	5.0	16	20
Acenaphthene	na	5.0	7593	5.0	477	20
Fluorene	na	5.0	259	5.0	26	20
Phenanthrene	na	5.0	1296	5.0	81	nu
Anthracene	na	5.0	6111	5.0	3837	20
PAHs in µg/kg						
Fluoranthene	na	5.0	741	5.0	47	20
Benzo(b)fluoranthene	a	5.0	a	nu	a	100
Pyrene	na	5.0	37	5.0	2.3	20
Benz(a)anthracene	na	5.0	37	5.0	2.3	100
Chrysene	na	5.0	183	2.0	12	100
Benzo(a)pyrene	na	5.0	2222	nu	140	100
Dibenz(a,h)anthracene	na	5.0	37	5.0	2.3	100
CDDs/PCDF in µg/kg	0.05	nu	0.01		0.01	
esticides/PCBs in µg/kg						
Total PCBs	140	10 - 600	631	10	39	40-80
Total DDT	160	2 - 20	20	2.20	1.3	8

. = not applicable
u = no undetected values measured
r = not recorded
a = not listed in QAPP Table 4-2.

Table 6-6. Concentrations of trace metals, PCBs, DDTs, and PAHs in fish tissues (wet weight)

Analyte	Milford Point		Lower Ferry Creek		Upper Ferry Creek	
	Min	Max	Min	Max	Min	Max
Trace Elements(mg/kg)						
Arsenic	0.42	0.48	0.44	0.68	0.49	0.55
Cadmium	0.009	0.018	0.012	0.02	0.023	0.14
Chromium	0.75	2.23	0.70	1.19	0.46	2.32
Copper	4.09	6.82	3.54	4.62	5.34	16.46
Lead	0.24	0.64	0.57	1.13	0.98	11.83
Mercury	0.011	0.015	0.01	0.017	0.01	0.015
Nickel	0.23	0.446	0.36	0.50	0.26	1.07
Silver	0.03	0.047	0.026	0.036	0.019	0.026
Zinc	39.27	42.8	39.2	44.5	44.98	58.67
DDTs and PCBs (µg/kg)						
4,4'-DDD	5 UJ	5	5 UJ	4	2 U	5 UJ
4,4'-DDE	5 UJ	10	5 UJ	6	5 UJ	6
4,4'-DDT	2 UJ	3	2 U	5 UJ	5 U	9 J
Aroclor 1016	10 U	20U	10 U	10 U	10 U	40 UJ
Aroclor 1221	10 U	20 U	10 U	10 U	10 U	180 UJ
Aroclor 1232	10 U	20 U	10 U	40 UJ	10 U	80 UJ
Aroclor 1242	10 U	20 U	10 U	40 UJ	10 U	40 UJ
Aroclor 1248	10 U	60 U	10 U	120 UJ	20 U	100 UJ
Aroclor 1254	10 U	80 U	10 U	80 UJ	50 U	120 UJ
Aroclor 1260	20	430	10 U	50	80 U	200 UJ
PCDDs and PCDFs (ng/kg)						
Total TCDD	.07 U	.1 U	0.1 U	0.3 U	.1 U	.2 U
Total PeCDD	.1 U	.16 NJ4	0.1 U	0.2 U	.1 U	.52 NJ4
Total HxCDD	.2 U	.98 NJ4	0.2 U	0.73 NJ4	.3 U	2.9
Total HpCDD	1.1 NJ4	3.4	3.2 NJ4	4.6	1.8	20.4
Total TCDF	1.4 NJ4	3 NJ3	0.2 U	0.54	.41 NJ4	4.7 NJ4
Total PeCDF	1.9	4.1 NJ4	0.88	1.4	1.3	6.9 NJ4
Total HxCDF	.68 NJ4	1.6 NJ4	0.39 J4	1.5 NJ4	.74 NJ4	9.3
Total HpCDF	1	3.2	1.1	2.2	.57 NJ4	8.4
2,3,7,8-TCDD TEQs	0.533	0.673	0.683	0.743	0.786	1.9
PAHs (µg/kg)						
2-Methylnaphthalene	5 U	5 U	5 U	5 U	5 U	5 U
Acenaphthene	5 U	5 U	5 U	5 U	5 U	5 U
Acenaphthylene	5 U	5 U	5 U	5 U	5 U	5 U
Anthracene	5 U	5 U	5 U	5 U	5 U	8
Benzo(a)anthracene	5 U	5 U	5 U	5 U	5 U	28
Benzo(a)pyrene	5 U	5	5 U	7	5 U	46
Benzo(b)fluoranthene	5 U	7	5 U	7	5 U	114
Benzo(g,h,i)perylene	5 U	5 U	5 U	5 U	5 U	34
Benzo(k)fluoranthene	5 U	5 U	5 U	10	5 U	5 U
Chrysene	5 U	5 U	5 U	8	5 U	62
Dibenz(a,h)anthracene	5 U	5 U	5 U	5 U	5 U	7
Fluoranthene	5 U	5 U	5 U	12	7	86
Fluorene	5 U	5 U	5 U	5 U	5 U	6
Indeno(1,2,3-cd)pyrene	5 U	5	5 U	5 U	5 U	41
Naphthalene	5 U	5 U	5 U	5 U	5 U	6
Phenanthrene	5 U	5 U	5 U	7	6	55
Pyrene	5 U	5 U	6	11	7	62
Total PAHs		12	6	60	21	546
%Lipids	1.75 U	1.96	1.35 U	1.69	1.46	1.71
%Solids	22.1	22.7	19.9	21.2	21.1	21.4

U — Undetected at the concentration not greater than the value shown.
J4 — Estimate due to interferences associated with standard.
NJ4 — Estimated maximum Possible Concentration; result is considered tentative.

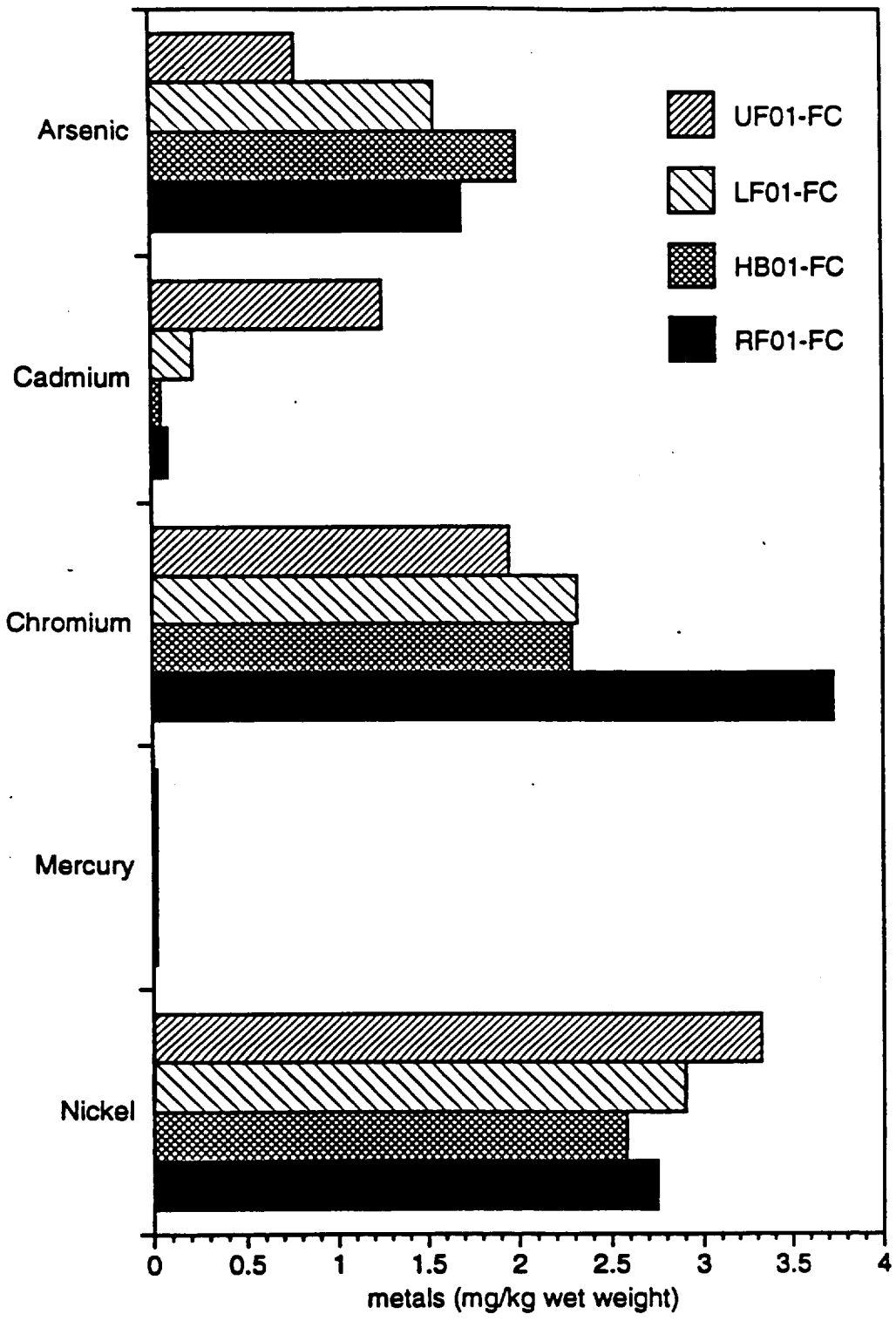

Figure 6-23. Metals concentrations in crab tissues collected from the Ferry Creek and Housatonic Boat Club Wetland and Milford Point Reference areas.

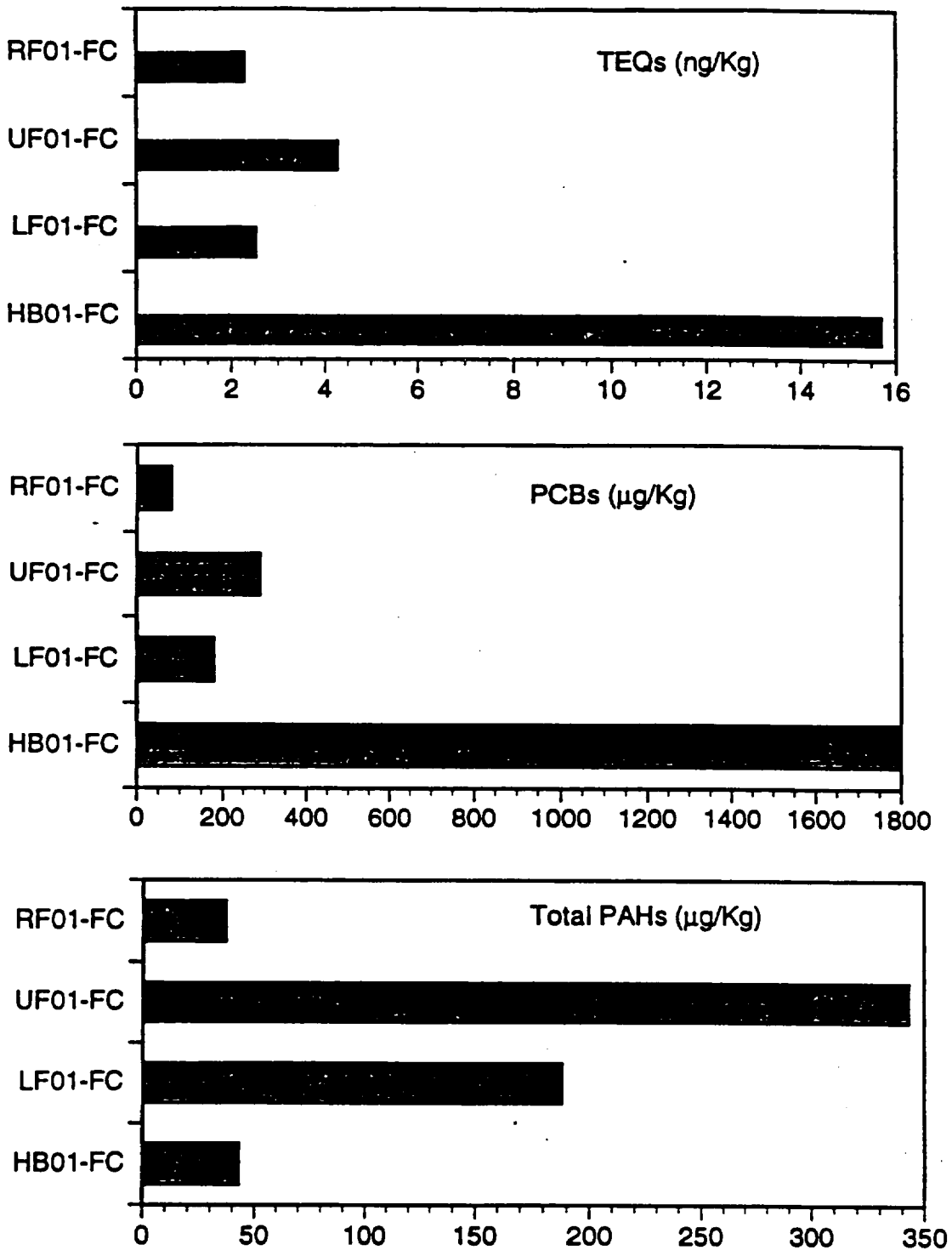

Figure 6-24. Concentrations of organics in crab tissues collected from the Ferry Creek and Housatonic Boat Club Wetland and Milford Point Reference areas.

Table 6-7. Concentrations of trace metals, PCBs, DDTs, and PAHs in crab tissues (wet weight)

Analyte	Milford Point	Boat Club wetlands	Lower Ferry Creek	Upper Ferry Creek
Trace Elements (mg/kg)				
Arsenic	1.70	2.00	1.55	0.73
Cadmium	0.09	0.05	0.22	1.26
Chromium	3.73	2.29	3.32	1.95
Copper	52.65	102.73	58.99	72.23
Lead	3.66	52.49	6.12	15.84
Mercury	0.02	0.02 U	0.02 U	0.02 U
Nickel	2.75	2.59	2.90	3.32
Silver	nr	nr	nr	nr
Zinc	23.48	27.14	27.14	27.37
DDTs and PCBs (µg/kg)				
4,4'-DDD	3 U	2 U	2 U	2 U
4,4'-DDT	2 U	20 U	3 U	5 U
4,4'-DDE	2 U	2 U	2 U	4 U
Aroclor 1016	10 U	10 U	10 U	10 U
Aroclor 1221	10 U	10 U	10 U	10 U
Aroclor 1232	10 U	10 U	10 U	10 U
Aroclor 1242	10 U	10 U	10 U	10 U
Aroclor 1248	10 U	10 U	10 U	10 U
Aroclor 1254	10 U	10 U	10 U	10 U
Aroclor 1260	60	1300	160	290
PCDDs and PCDFs (ng/kg)				
Total TCDD	0.09 NJ4	0.2 U	0.4 NJ4	0.2 U
Total PeCDD	1.3 NJ4	0.84 NJ4	1.5 NJ4	1.8 NJ4
Total HxCDD	504	3.2	8.1 NJ4	8.6
Total HpCDD	7.9	6.1	19.5 NJ4	42.8
Total TCDF	11.2 NJ4	43 NJ4	10.1 NJ4	11.7 NJ4
Total PeCDF	11 NJ4	69.1 NJ4	12.1 NJ4	17.4 NJ4
Total HxCDF	6.8 NJ4	52.1	9.7 NJ4	19 NJ4
Total HpCDF	7.3 NJ4	16.5 NJ4	6.9 NJ4	16.3
2,3,7,8-TCDD TEQs	2.29	15.7	2.52	4.28
PAHS (µg/kg)				
Naphthalene	5 J	5 UJ	6 J	5 UJ
Acenaphthylene	5 UJ	5 UJ	5 UJ	5 UJ
Acenaphthene	5 UJ	5 UJ	5 UJ	5 UJ
Fluorene	5 UJ	5 UJ	5 UJ	5 UJ
Phenanthrene	5 UJ	5 UJ	8 J	16 J
Anthracene	5 UJ	5 UJ	5 UJ	5 UJ
Fluoranthene	5 UJ	5 UJ	20 J	53 J
Pyrene	5 UJ	5 UJ	27 J	54 J
Benzo(a)anthracene	5 UJ	5 J	8 J	20 J
Chrysene	5 UJ	13 J	16 J	31 J
Benzo(b)fluoranthene	9 J	12 J	20 J	33 J
Benzo(k)fluoranthene	6 J	6 J	15 J	27 J
Benzo(a)pyrene	6 J	7 J	17 J	30 J
Indeno(1,2,3-cd)pyrene	5 J	5 UJ	20 J	35 J
Dibenz(a,h)anthracene	5 UJ	5 UJ	10 J	9 J
Benzo(g,h,i)perylene	6 J	5 UJ	21 J	44 J
Total PAHs	37	43	188	352
% Lipd	1.06	0.93	1.21	0.97
%Solids	32.7	32.2	32.2	31

nr — not reported
U — Undetected at the concentration not greater than the value shown.
NJ4 — Estimated maximum Possible Concentration; result is considered tentative.

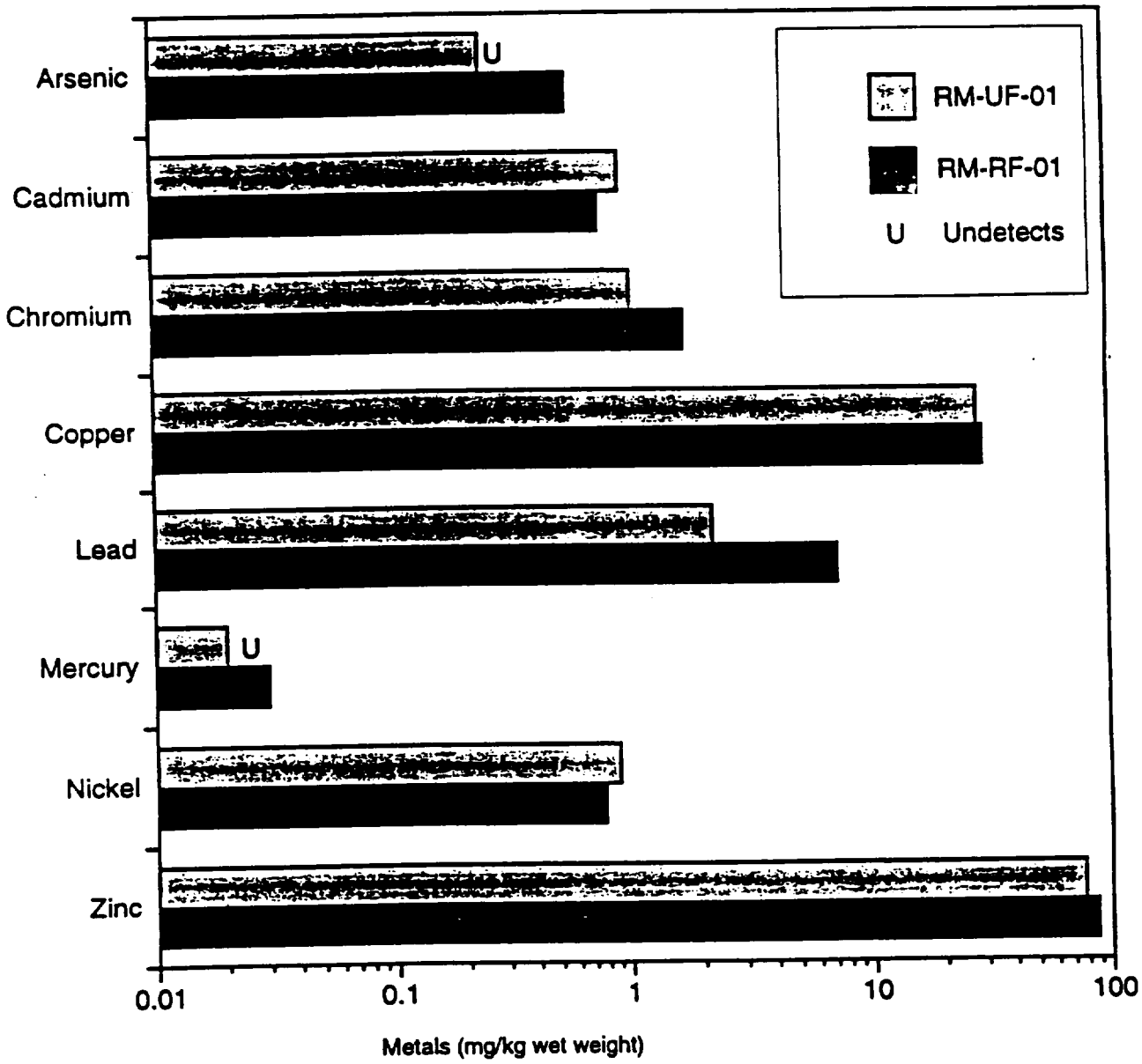

Figure 6-25. Metals concentrations in insect tissues collected from the Ferry Creek and Milford Point Reference areas.

Table 6-8. Concentrations of trace metals, PCBs, DDTs, and PAHs in insect tissue composites (wet weight).

Analyte	Milford Point	Upper Ferry Creek
Trace Elements (mg/kg)		
Arsenic	0.56	0.24 U
Cadmium	0.78	0.94
Chromium	1.73	1.04
Copper	29.69	28
Lead	7.20	2.22
Mercury	0.03 UJ	0.02 UJ
Nickel	0.78	0.90
Zinc	87.05	77.6
DDTs and PCBs (µg/kg)		
4,4'-DDD	8 U	8 U
4,4'-DDT	8 U	8 U
4,4'-DDE	8 U	8 U
Aroclor 1016	40 U	40 U
Aroclor 1221	40 U	40 U
Aroclor 1232	40 U	40 U
Aroclor 1242	40 U	40 U
Aroclor 1248	40 U	40 U
Aroclor 1254	40 U	40 U
Aroclor 1260	40 U	80 U
PCDDs and PCDFs (µg/kg)		
Total TCDD	0.8 J	0.84J
Total PeCDD	2.3 J	0.65 UJ
Total HxCDD	8 J	4.6 UJ
Total HpCDD	32.5 J	66.3 J
Total TCDF	7.2 J	3.2 J
Total PeCDF	5.1 UJ	3.7 J
Total HxCDF	4.4 UJ	5.3 UJ
Total HpCDF	2.8 UJ	13.9 J
2,3,7,8-TCDD TEQs	1.38	2.23
PAHs (µg/kg)		
Naphthalene	20 U	20 U
Acenaphthylene	20 U	20 U
Acenaphthene	20 U	20 U
Fluorene	20 U	20 U
Phenanthrene	47	26
Anthracene	20 U	20 U
Fluoranthene	20 U	20 U
Pyrene	20 U	20 U
Benzo(a)anthracene	100 U	100 U
Chrysene	100 U	100 U
Benzo(b)fluoranthene	100 U	100 U
Benzo(k)fluoranthene	108	100 U
Benzo(a)pyrene	100 U	100 U
Indeno(1,2,3-cd)pyrene	186	150
Dibenz(a,h)anthracene	100 U	100 U
Benzo(g,h,i)perylene	100 U	100 U
Total PAHs	341	176
% Lipid	12.0	7.8
%Solids	55.8	47.3

U — Undetected at the concentration not greater than the value shown.
J — Estimate

7.0 EFFECTS ASSESSMENT

Ecological effects of a contaminant on an ecosystem may be immediate or delayed, permanent or reversible, direct or indirect. Investigative methods to assess these effects may also be either direct or indirect. In this risk assessment, both direct bioassessment methods and indirect modeled approaches are used to assess the potential for, or the actual occurrence of, adverse ecological effects. The direct methods include measurements of the bioaccumulation of CoCs, toxicity tests for acute and chronic toxicity, and surveys of the benthic community with interpretive analysis of its structure. Indirect, comparative, and predictive models were used to contrast ambient exposures or doses of CoCs to benchmark values. Site-specific data from the field-sampling effort serve as inputs for the exposure portion of the models, while the effects benchmarks come from scientific literature.

7.1 SEDIMENT TOXICITY RESULTS

Toxicity from exposure to CoCs present in sediment was assessed using three bioassessment tools: two sediment-toxicity tests and a survey of the indigenous benthic community. The two sediment-toxicity tests—an amphipod test and the oyster larvae test—assessed the acute lethality of sediment by exposing test organisms to environmental samples under controlled, laboratory conditions. The survey of the indigenous benthic community established the structure of the infaunal macroinvertebrate community at each location. This section presents the results from these bioassessment measures. The complete laboratory reports for each analysis are included as Appendices A through C of this report.

7.1.1 Amphipod Acute Lethality Bioassay

The results of the 10-day *Leptocheirus plumulosus* test are summarized in **Table 7-1.** The test was considered valid since mean survival in the control sediment (92.5%) met the acceptability criterion set by ASTM (1994a). A good, broad range in response was observed which helps provide discriminatory power to the results. Survival data were transformed using an arcsine square root function and tested for normality (Shapiro-Wilk's test) and for homogeneity of variance (Bartlett's test). The transformed survival data passed both of these tests.

The lowest mean amphipod survival was 30% in the sediment sample collected from Station SD07, located below the tide gate in Ferry Creek. However, the variability among replicates of this sample was the highest observed. This may indicate poor laboratory procedure, or lack of homogeneity in the sediment replicates. Very low survival (31%) was also observed in the sample collected from Station SD21 located in Upper Ferry Creek. This sample had the second largest standard deviation among replicates. The highest mean amphipod survival results were 99% in sediment collected from RF01, the reference area in Beaver Brook, and 98% in sediment from HB06, located in the western portion of the Housatonic Boat Club wetlands.

Individual samples were identified as "toxic" by virtue of diminished survival due to responses to the CoCs in the sample. Statistical comparisons (ANOVA followed by Fisher's PLSD) were made between mean responses observed in the five laboratory replicates of each single sample versus those observed in the appropriate reference area sample(s). Because of the potential effect of grain size on amphipod survival, samples were matched based on their grain size, as defined by percent fines content. Results of these comparisons indicated that three of the nine samples were classified as toxic—SD21 from Upper Ferry Creek ($p<0.0001$); SD13 from Upper Ferry Creek ($p<0.0035$); and SD07 from Lower Ferry Creek ($p<0.0001$;

Table 7-1. Summary of results of the 10-day *Leptocheirus plumulosus* sediment toxicity test.

Sample	Reference sample [a]	Mean survival (%) [b]	Toxic [c]	Avoidance [d] (mean ± sd)
HB-06	RF-01	98.0	No	0.3 ± 0.1
HB-12	RF-02/03	88.0	No	0.2 ± 0.3
HB-23	RF-02/03	78.0	No	0.1 ± 0.1
SD-07	RF-01	30.0	Yes	0.4 ± 0.2
SD-10	RF-02/03	92.0	No	0.2 ± 0.1
SD-13	RF-02/03	58.0	Yes	0.3 ± 0.2
SD-19	RF-02/03	79.0	No	0.2 ± 0.1
SD-20	RF-01	77.0	No	0.2 ± 0.2
SD-21	RF-01	31.0	Yes	0.6 ± 0.3
RF-01	na	99.0	na	0.4 ± 0.2
RF-02	na	83.0	na	±
RF-03	na	78.0	na	0.1 ± 0.1
Control Sediment	na	92.5	na	0.1 ± 0.1

[a] Corresponding reference station with similar grain size.
[b] Five replicates, except for Control Sediment, which had four replicates.
[c] Statistically significant reduction in mean survival of sample replicates when compared with response of reference sample replicates.
[d] Number of amphipods on the sediment surface per jar per day (out of a maximum of 20).
na — not applicable

Table 7-1). Because sediment sampling stations were selected to encompass a range in contamination levels, it was not expected that all samples would be toxic.

Mean avoidance in the laboratory replicates of test sediments ranged from zero amphipods/jar/day in the sediment sample collected from RF02 to 0.6 amphipods/jar/day for the sample from SD21. This was one of the samples identified as toxic. Mean avoidance in the control sediment sample was 0.1 amphipods/jar/day.

The two samples with the greatest toxicity contained elevated levels of total PCBs and total PAHs. Sample SD21 from Upper Ferry Creek also had the highest TCDD TEQs and the second highest SEM/AVS ratio (7.7), which was sufficiently high to suggest that bioavailable divalent trace metals were present.

Statistical comparisons (Kruskal-Wallis with multiple contrasts) of mean survival and avoidance between the mean response observed in the three samples each from Upper Ferry Creek, Lower Ferry Creek, and the boat club wetlands versus the reference samples were also conducted. This test distinguished areas where the mean response was statistically different than that of the reference area. There were significant differences ($p=0.0003$) in survival, with the Ferry Creek areas exhibiting lower survival than either the reference or boat club wetland area samples. For the avoidance measure, differences were indicated at a p-value of 0.06, with

the only distinguishable area being Upper Ferry Creek, which had significantly greater avoidance than the reference area. The highest avoidance was observed in an Upper Ferry Creek sample (SD-SD21). Avoidance of test sediments can be another indication that the nature of the test samples is noxious, distasteful, or somehow stressful to the organisms. Since avoidance would tend to lower exposures to sediments and pore water, it can be a confounding factor with the survival endpoint, although avoidance is not generally viewed as strong a response to contamination as is mortality.

7.1.2 Oyster Larvae Developmental Bioassay

The results of the *Crassostrea gigas* larval development test are presented in **Table 7-2.** The mean percent abnormality and mean percent combined mortality in the seawater control were within the criteria limits for test acceptance of 10% abnormality (ASTM 1994a) and ≤50% combined mortality (PSDDA 1989). Mean percent abnormality and mean percent combined mortality in the seawater control were 2.7% and 4.3%, respectively. There was also a broad range in responses observed which lends itself to good discriminatory ability. Survival data were transformed using an arcsine square-root function and tested for normality (Shapiro-Wilk's test) and for homogeneity of variance (Bartlett's test). The abnormality data passed both of these tests. The combined mortality data passed the test for normality but not for homogeneity of variance. ANOVA is quite robust to uneven variance, particularly when sample sizes are equal as in this case (Zar 1984). Therefore, these data were evaluated with parametric statistical tests. Tests of abnormality reflect the developmental toxicity potential of samples, while the mortality endpoint reflects acute toxicity. Because abnormal larvae are assumed to be inviable, these two counts are summed for the combined mortality figure. This value is thought to reflect the longer term, overall toxicity potential.

Table 7-2. Summary of results of 48-h *Crassostrea gigas* larval development test.

Sample	Mean [a] Abnormality (%)	Toxic [b]	Mean Combined Mortality[c] (%)	Toxic [b]
HB-23	20.3 ± 3.2	Yes	83.7 ± 2.8	Yes
SD-10	12.2 ± 2.3	No	34.7 ± 1.9	No
SD-13	47.4 ± 4.1	Yes	79.4 ± 2.3	Yes
RF-02	11.7 ± 1.9	na	43.7 ± 7.2	na
Sediment Control	4.1 ± 0.7	na	3.1 ± 4.3	na
Seawater Control	2.7 ± 1.0	na	4.3 ± 10.1	na

[a] Mean of the five replicates

[b] Statistically significant increase in mean abnormality of sample replicates when compared with response of reference sample replicates.

[c] Mean combined mortality = mean abnormality + mean mortality.

Mean percent abnormality in the laboratory replicates of sediment samples ranged from 11.7% in the reference area sample (RF02) to 47.4% in the sample from Upper Ferry Creek (SD13). Average percent combined mortality (mortality plus abnormality) ranged from 34.7% in the Lower Ferry Creek sample (SD10) to 83.7% in the sample from the boat club wetlands (HB23).

Statistical comparisons (ANOVA followed by Fisher's PLSD) were made between mean responses observed in the five laboratory replicates of the single sample from each station versus those observed in the controls, and also against the mean in laboratory replicates from the reference area sample (RF02). This comparison identified those samples which, by virtue of their content of CoCs, had toxic responses significantly different from those observed in the controls. Two endpoints are examined because toxic constituents may exert either acute lethality or, if acutely non-lethal, may interfere with development to produce deformed larvae which are assumed to be non-viable. Dioxin is a good example of a toxin which tends to act through a latent, developmental mode of action. Results for mean percent abnormality and combined mortality are also presented in Table 7-2. Two of the three site-related samples were thus identified as toxic. The sample from the Housatonic Boat Club wetland, HB23, was identified as toxic by both the abnormality and combined mortality endpoints ($\rho=0.0003$ and $\rho<0.0001$, respectively). The sample from Station SD13 in Upper Ferry Creek was also identified as toxic by both measures ($\rho<0.0001$ for both). Although parametric tests are relatively robust with regard to homogeneity of variance (Zar 1984), non-parametric Kruskal-Wallis tests were also conducted to confirm results. Significant differences were again indicated at only slightly lower ρ values.

The two toxic samples that exhibited the greatest reduction in viability of larvae (HB23 and SD13) were also the samples containing some of the highest levels of total PCBs and TCDD TEQs. Both also contained above-average total PAHs. The sample from the boat club wetlands also had the greatest ratio of SEM/AVS, indicating potentially bioavailable, divalent trace elements in this sample. The remaining, non-toxic sample from the mouth of Ferry Creek (SD10) was not expected to be toxic due to lower contaminant concentrations at this locale.

Statistical comparisons (Students *t* test) were made between mean responses of the three site-related samples (i.e., Upper and Lower Ferry Creek plus the Housatonic Boat Club wetlands) versus the value of the mean response observed from the reference sample to further address the question of whether site-related sediments containing CoCs were capable of causing adverse ecological impacts. Despite the low statistical power enabled by only three samples in the areas of interest, differences between the mean percent abnormality or combined mortality associated with site-related samples versus the mean value observed in the reference sample were indicated at a ρ-value of 0.15.

7.2 BENTHIC INVERTEBRATE COMMUNITY STRUCTURE

Analyses of benthic community structure are often aimed primarily at pattern detection (as opposed to *a priori*, controlled, experimental testing). The objective of pattern detection is to confirm hypotheses concerning the structure of ecological communities (Ludwig & Reynolds 1988). Three basic patterns are recognized in communities: random, clumped, and uniform (Ludwig & Reynolds 1988). Randomness in a community tends to confirm environmental homogeneity and non-selective patterns. Clumping suggests that individuals are aggregated according to areas of more (or less) favorable conditions. A uniform (i.e., non-random) dispersion suggests that negative interactions between individuals (e.g., competition for food or space) may be the primary controlling distributional factor. When the unit size of the area sampled is sufficiently smaller than the clumping pattern, observational assessments are able to detect differences between investigative areas. Any differences observed are likely due to some combination of environmental stressors that creates more and less favorable habitats.

For benthic macroinvertebrate community assessments, pattern detection usually focuses on analysis of species richness, species evenness, and diversity. Species richness is simply the number of species in the community. When sample sizes between investigative areas are even, richness should be even as well (richness can be affected by the degree of sampling effort).

Species evenness refers to the equitability of how species abundance (e.g., the number of individuals, biomass, cover) is distributed among the species present. Diversity incorporates these two factors into a single index. Since diversity is a combination of two factors, it responds to changes in richness or evenness either singularly or both concurrently. Interpretation of diversity indices thus requires caution.

For this risk assessment, four sediment grabs (samples) were collected at each of the following seven stations to identify and count benthic macroinvertebrates:

- Upper Ferry Creek SD13, SD20;
- Lower Ferry Creek SD07, SD19;
- Housatonic Boat Club HB23;
- Beaver Brook RF01 (as a low-salinity station); and
- Milford Point RF02 (as a high-salinity station).

Station RF01 is located in the tidally influenced, low-salinity section of Beaver Brook and represents a reference area for comparison with Upper Ferry Creek Stations. Station RF02 is located in a tidal channel of a *Spartina* wetland near Milford Point. This station represents a reference area for comparison to Lower Ferry Creek and Housatonic Boat Club stations.

Macroinvertebrates were identified to the lowest taxon practical and enumerated. A complete listing of the species found and their occurrence is provided as Appendix C. Counts were transformed to densities in units of individuals per square meter. These data appear in **Table 7-3** as mean total abundance (density) and taxa richness (as number of species present) by station. **Table 7-4** summarizes and compares these data. Data were also summarized and compared by the following major groupings: annelids, arthropods, amphipods, insects, and molluscs **(Tables 7-5 through 7-9)**. Nematodes occurred in only a very few replicates and were not considered in further analysis. All data were statistically evaluated by non-parametric Kruskal-Wallis tests versus only the appropriate reference station. All conclusions of significant difference were based on ρ values of 0.05 or better and one-way multiple comparisons.

7.2.1 Total Abundance

The total abundance, or density, of benthic organisms in sediment samples from Ferry Creek stations SD07, SD19, SD13, SD20; Housatonic Boat Club station HB23; and the reference stations in Beaver Brook (RF01) and Milford Point (RF02) are presented in Table 7-4. There was a nearly tenfold range in total mean infaunal density. Mean total density ranged from a low of 2,982 individuals/m^2 at station HB23 to 29,732 individuals/m^2 at the Beaver Brook reference station RF01.

Differences in mean total density were indicated for the Upper Ferry creek stations at a ρ value of 0.1 (0.056 for parametric ANOVA), with both stations having substantially lower density than the reference. There were no significant differences in density among the high-salinity stations of Lower Ferry Creek and the boat club wetlands. Station SD07 had the highest density, driven by *Capitella*, but also displayed high variance among the four samples.

Table 7-3. Density (individuals/m²) of benthic organisms.

	SAMPLING STATIONS						
	HB-23	SD-07	SD-19	RF-02	SD-20	SD-13	RF-01
Taxa NEMATODA	65	366		248			
ANNELIDA	1,722	9,850	3,789	4,500	9,495	13,639	11,949
Ampharetidae						22	
Capitella capitata complex		7,094				11	
Glycera spp.				11			
Hobsonia florida		409	86		205	1,443	8,128
Hypereteone heteropoda	11	463	1,012	1,033		11	
Laeonereis culveri	11	291	11		32	3,509	118
Marenzellaria viridis							334
Mediomastus ambiseta				54			
Neanthes spp.		32		43			
Neanthes succinea		161	183	129			
Neanthes virens		75					
Nereis spp.							
Oligochaeta	1,701	1,109	710	1,399	9,258	8,623	3,348
Polydora cornuta		151	280	22			
Streblospio benedicti		65	1,507	1,798		22	
ARTHROPODA	161	205	11	710	32	43	14,048
Almyracuma proximocuii							11
Balanus improvisus		151					
Cassidinidea ovalis							22
Cyathura polita		11			22	32	775
Edotea triloba		11		54			
Uca spp.	22						
Amphipods	140	22	11	625	11	11	13,230
Caprella penantis				11			
Corophium lacustre	11		11				409
Gammarus palustris	118						
Gammarus tigrinus		11			11	11	8,913
Leptocheirus plumulosus				614			3,908
Melita nitida		11					11
Melitidae				11			
Microgammarus mucronatus		11		11			

Table 7-3 continued

TAXA	SAMPLING STATIONS						
	HB-23	SD-07	SD-19	RF-02	SD-20	SD-13	RF-01
Amphipods	140	22	11	625	11	11	13,230
Microprotopus raneyi				11			
Talitridae	11						
INSECTA	689	129			75		3,735
cf. Aericotopus spp.							22
Chironomidae							22
Chironomini							65
Chironomus spp.	11				11		1,249
Clinotanypus spp.							11
Culicoides spp.	635				11		
Dicrotendipes spp.					43		1,464
Diptera pupae	11						
Empididae (Diptera) larvae	22						
Hemiptera		129					
Muscidae (Diptera) larvae	11						
Polypedilum spp.							43
Procladius spp.							614
Tanypoidini					11		
Tanypus spp.							11
Tanytarsus spp.							237
MOLLUSCA	344		65	194			
Gemma gemma				11			
Littoridinops tenuipes				86			
Hydrobia spp.	344						
Macoma balthica			43	97			
Mya arenaria			22				
Mean Total Abundance	2,982	10,550	3,865	5,652	9,602	13,682	29,732
Mean Taxa Richness (as no. of species)	7	11	7	11	5	5	16

Table 7-4. Comparison of total benthic infaunal abundance for Ferry Creek, Housatonic Boat Club, and reference stations.

Station	Reference Station [a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	2,982	± 1,092	No
SD-07	RF-02	10,560	± 3,267	No
SD-13	RF-01	13,682	± 5,757	Yes
SD-19	RF-92	3,865	± 1,582	No
SD-20	RF-01	9,602	± 3,821	Yes
Reference Station				
RF-01		29,732	±1,615	na
RF-02		5,652	± 1,202	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

7.2.2 Annelid Abundance

The mean density of annelids ranged from 1,722 individuals/m^2 at station HB23 to 13,639 individuals/m^2 at station SD13 (**Table 7-5**). Annelids represented between 40% and 99% of the total abundance of benthic organisms in the stations sampled.

Oligochaetes were the most abundant type of annelid present in the samples. The ampharetid *Hobsonia florida* was the most abundant polychaete present. The polychaete *Capitella capitata* was abundant in some grabs from station SD07. *Capitella* are known as a pollution-tolerant species characteristic of degraded, highly organically-enriched sediments.

Table 7-5 also lists results of the statistical comparisons for density of annelids found in Ferry Creek and the Housatonic Boat Club sediments relative to reference sediments. The density of annelids was not statistically lower at any stations. However, Upper Ferry Creek stations exhibited much greater variability in density of annelids than their reference station, thus imparting low power to any statistical tests. As noted above, increased abundance of annelids at SD07 was due largely to the relatively high occurrence of *Capitella*, a pollution-tolerant species.

7.2.3 Arthropod Abundance

The mean density of arthropods ranged from 11 individuals/m^2 at Lower Ferry Creek static SD19 to a high of 17,783 individuals/m^2 at the reference station RF01 (**Table 7-6**). Arthropoc composed between <1% and 60% of the total abundance of benthic organisms. Crustacear composed between 30% and 100% of the arthropods present, and ranged in density from 1 individuals/m^2 at station SD19 to 14,048 individuals/m^2 at station RF01 (Table 7-3). Insec composed between 0% and 70% of the arthropods present, ranging from totally absent stations SD13, SD19 and the saline reference station RF02 to 3,735 individuals/m^2 at RF01.

Table 7-5. Comparison of annelid abundance at Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	1,722	± 649	No
SD-07	RF-02	9,850	± 3,001	No
SD-13	RF-01	13,639	± 5,763	No
SD-19	RF-02	3,789	± 1,539	No
SD-20	RF-01	9,495	± 3,352	No
Reference Station				
RF-01		11,949	± 374	na
RF-02		4,500	± 870	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

Table 7-6. Comparison of arthropod abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	850	± 576	No
SD-07	RF-02	334	± 130	No
SD-13	RF-01	43	± 26	Yes
SD-19	RF-02	11	± 9	Yes
SD-20	RF-01	107	± 36	Yes
Reference Station				
RF-01		17,783	± 1,430	na
RF-02		710	± 354	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

Crustaceans were the most abundant arthropods at stations SD13, SD19, RF01, and RF02, while insects dominated the arthropod abundance at HB23 and SD20. The most abundant of the benthic crustaceans were the amphipods *Gammarus palustris, G. trigrinus,* and *Leptocheirus plumulosus*. Amphipods are considered sensitive indicator species and are among the first to disappear in pollution-impacted areas (Lamberson et al. 1992). Gammarids and *Leptocheirus p.* are being used as test organisms in toxicity tests partly due to their sensitivity. One of the toxicity tests used in this assessment employed *Leptocheirus plumulosus* as the test species. In the native sediment samples, *L. plumulosus* was found only in samples from the two reference stations.

Results of the statistical comparisons for density of arthropods, amphipods, and insects relative to their appropriate reference stations are found in **Tables 7-6, 7-7, and 7-8.** The

density of all arthropods was statistically lower at Upper Ferry Creek stations (SD 13 and SD20) and station SD19 in Lower Ferry Creek. Amphipod density was statistically depressed at all stations relative to their reference area. Amphipods were functionally absent in samples from Upper Ferry Creek as only one amphipod was present in the four grabs each at stations SD13 and SD20. There was only one individual observed in all grabs from SD19, and only three in all samples from station SD07. Insect density was statistically lower at both Upper Ferry Creek stations. In fact, insects were absent at station SD13. The functional absence of both insects and amphipods in Upper Ferry Creek emphasizes the degraded conditions of this locale.

Table 7-7 Comparison of amphipod abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station [a]	Abundance (per m^2) [b]	Standard Error	Impacted [c]
HB-23	RF-02	140	± 84	No
SD-07	RF-02	32	± 18	Yes
SD-13	RF-01	11	± 9	Yes
SD-19	RF-02	11	± 9	Yes
SD-20	RF-01	11	± 9	Yes
Reference Station				
RF-01		13,241	± 1,124	na
RF-02		646	± 331	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

Table 7-8. Comparison of insect abundance at Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station [a]	Abundance (per m^2) [b]	Standard Error	Impacted [c]
HB-23	RF-02	689	± 423	na
SD-07	RF-02	129	± 100	na
SD-13	RF-01	0	± 0	Yes
SD-19	RF-02	0	± 0	na
SD-20	RF-01	75	± 34	Yes
Reference Station				
RF-01		3,735	± 256	na
RF-02		0	± 0	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared to reference.

7.2.4 Molluscan Abundance

Molluscs were expected only at higher-salinity stations HB23, SD19, SD07, and RF02. The mean density at these stations ranged from zero at SD07, to 65 individuals/m^2 at station SD19, to 344 individuals/m^2 at HB23. Molluscs were uncommon, representing only 0% to 11% of the total abundance of benthic organisms in these samples.

Results of the statistical comparisons for density of molluscs found in Lower Ferry Creek and the Housatonic Boat Club wetland sediments, relative to their appropriate reference stations, are found in **Table 7-9**. The absence of molluscs at station SD07 was the only statistically significant difference from the reference area. Both SD07 and SD19 are in Lower Ferry Creek, which has saline, tidal water incursions. Based on salinity alone, there is no apparent reason for the lack of molluscs at just one of these stations.

Table 7-9. Comparison of mollusc abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	344	±58	No
SD-07	RF-02	0		Yes
SD-13	RF-01	0		na
SD-19	RF-02	65	±65	Yes
SD-20	RF-01	0	±0	na
Reference Station				
RF-01		0	±0	na
RF-02		194	±44	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

7.2.5 Taxa Diversity, Richness, and Evenness

A wide variety of indices have been developed to describe and contrast various aspects of community structure (i.e., species abundance relationships). Diversity, one of the most common indices reported, is actually composed of two elements: species richness or the total number of different species present, and species evenness or how abundance is distributed among the species. Diversity indices attempt to combine both these elements into a single value. Care must be taken in interpreting diversity indices, however, since they respond to these two separate components either in concert or independently.

For this assessment, two different indices of species richness were calculated: Those of Margalef (1958) and Menhinick (1964). Low values in both indices indicated low species richness or dominance by only a few species. Because species-richness indices are heavily influenced by sample sizes, the utility of calculated indices depends upon adequate and comparable sample sizes. An alternative to species-richness indices, when sample sizes at all

locations are equal, is simply a count of the number of species present. Rarefraction is yet another species-richness procedure that calculates the probabilities of observing an expected number of species present over a range of sample sizes, using observed data from samples of varying sizes. The goal of rarefraction is to eliminate the bias to which other indices are subject when sample sizes vary. The probabilities obtained from rarefraction can be projected graphically, which then allows for interpretation at any given sample size. Although sample sizes were even in this study, rarefraction has been used to portray results in an intuitive, graphical manner.

Because species-richness indices are also overly sensitive to the presence of rare species, species evenness is another key aspect of community structure to examine. Optimally, an evenness index should be independent of the number of species present in a sample (i.e., species richness). Alatolo's evenness index tends to be independent of sample size and is relatively unaffected by species richness. It is also less sensitive to the presence of rare species. Therefore, the evenness index of Alatolo (1981) was also calculated for this effort. This index value approaches zero as a single species dominates the benthic community.

For overall species-diversity indices, the diversity numbers of Hill (1973) were calculated. For diversity indices, these numbers have intuitive appeal and are easy to interpret because they are expressed in units of species. Hill refers to them as the effective number of species present. His simplest index, the N0 value, is simply the number of species present, regardless of their abundance. As such, this is essentially a *de facto* species-richness figure. Hill's other indices, N1 and N2, represent the number of abundant and very abundant species, respectively.

Indices of diversity, richness, and evenness for benthic organisms present in sediment samples from Ferry Creek stations, SD07, SD13, SD19, SD20; Housatonic Boat Club station HB23; and the reference stations in Beaver Brook, RF01 and Milford Point, RF02 are presented in **Table 7-10**. Rarefraction curves based on mean values for each station for these samples are presented in **Figure 7-1**.

Mean species richness, as represented by the number of species present (i.e., N0), ranged from 4.5 taxa per grab at station SD13 or SD20, to 16.25 taxa per grab at the reference station RF01. There was a threefold range in Menhinick's richness index, with the lowest values observed for Upper Ferry Creek stations SD13 and SD20. Additionally, Hill's overall diversity indices of N1 and N2 indicated strong dominance by few species in Upper Ferry Creek, with only one or two species classified "very abundant" and only two or three classified as "abundant," as opposed to over six abundant species and almost five very abundant species at the reference stations. This pattern of species dominance is also reflected in the low evenness value for grabs from station SD20. Dominance by annelids in grabs from station SD07 is also indicated by the low evenness value for that station.

Upper Ferry Creek stations were compared with the lower-salinity reference station in Beaver Brook. All benthic community measures (species abundance, species richness, and density of individuals) were significantly reduced at the Upper Ferry Creek stations. These stations were dominated by three to four abundant species, and only one or two very abundant species. There was significantly lower evenness at SD20, where oligochaetes dominated: over 96% of the individuals were oligochaetes. Together with just two annelid species, these species accounted for 99% of the individuals present at this Upper Ferry Creek station.

Table 7-10. Indices of diversity, evenness, and richness for benthic community structure.

Station	Total Count	Diversity					Evenness	Richness	
		NO [a]	H' [b]	N1 [c]	λ [d]	N2 [e]	E [f]	R [g]	R [h]
HB23	2,984	14	1.33	3.77	0.39	2.59	0.58	1.62	0.26
SD07	10,551	18	1.34	3.83	0.47	2.13	0.40	1.84	0.18
SD19	3,865	10	1.56	4.77	0.26	3.81	0.75	1.09	0.16
RF02	5,643	18	1.84	6.30	0.21	4.73	0.70	1.97	0.24
SD20	9,604	9	0.21	1.23	0.93	1.08	0.33	0.87	0.09
SD13	13,684	9	0.93	2.53	0.47	2.11	0.72	0.84	0.08
RF01	2,9715	21	1.91	6.73	0.20	4.99	0.70	1.94	0.12

[a] Cumulative number of species present among all four grabs.

[b] Shannon's index. Average degree of uncertainty in predicting what species a random individual came from. Used in calculating N1.

[c] Number of abundant species. Lower value indicates an increase in dominance by fewer species

[d] Probability that two random individuals sampled are from same species. Inverse with diversity. Used in calculating N2.

[e] Number of very abundant species. Lower value indicates an increase in dominance by fewer species.

[f] Alatolo 1981

[g] Margalef 1958

[h] Menhinick 1964

Lower Ferry Creek stations and the boat club wetland station were compared with the reference station at Milford Point (RF02). Species abundance, species richness, and density of individuals were all significantly reduced at the boat club wetland station, HB23, compared with the reference, although stations in Lower Ferry Creek exhibited more erratic patterns. Richness indices of Margalef (1958) and Menhinick (1964) were both highly variable among grabs at the Lower Ferry Creek stations. Samples from SD19 had significantly reduced richness of taxa and dominance by only three abundant species. At SD07, there was a high number of individuals, but with great variability between grabs. Richness of taxa was high, but this was due to rare occurrences (as discussed above). This station also was dominated by only two very abundant and three to four abundant species. This dominance was further reflected by the significantly reduced evenness.

7.2.6 Overall Benthic Community Impacts

Results of calculations for the various benthic community diversity parameters, evenness, richness, and abundance (Table 7-10) plus rarefraction curves of Figure 7-1 clearly indicate that the benthic community present at Upper Ferry Creek stations (SD13 and SD20) is seriously degraded. These stations have depressed abundance, richness, and evenness, which all combine for significantly depressed diversity. In the rarefraction curves, this trend is indicated by the low number of species expected, less than four, regardless of sample size.

The stations HB23 and SD19 also indicate a degraded benthic community. These stations are not as severely impacted as the Upper Ferry Creek stations, but clearly are still distinct from the reference stations. The expected number of species is lower than the reference areas, confirmed by the dominance indices. There were only three to four abundant or very abundant species at these stations.

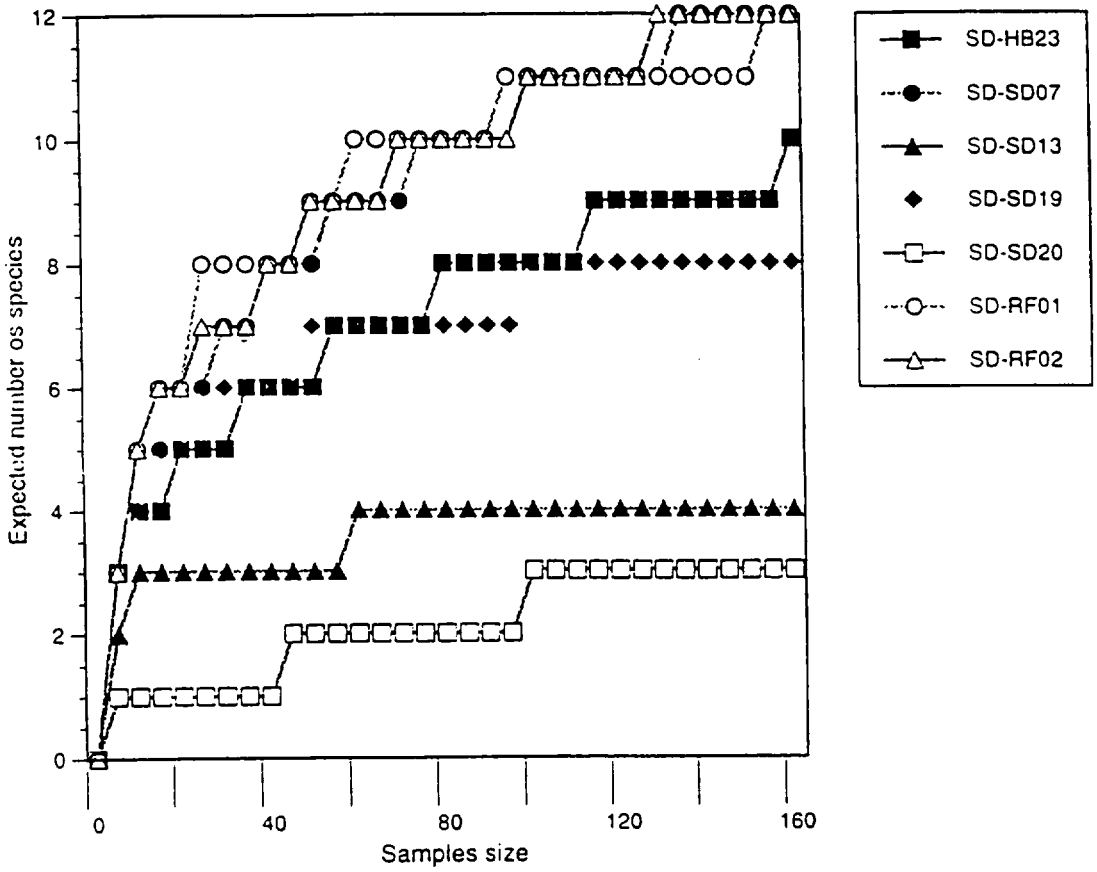

Figure 7-1. Rarefraction curves indicating number of benthic species expected for various sample sizes.

Although station SD07 plots out in the rarefraction curves (Figure 7-1) with the reference stations, as discussed above, this station is an anomaly. The number of species present at this station was comparable to the reference stations only because of the rare occurrence of one or two individuals in only one or two of the four grabs. The evenness, dominance, and richness would all suggest that diversity at the station is diminished and is comparable to HB23 or SD19. This station is also unique for the high incidence of *Capitella*, plus the relatively high TOC (5.2%) for such a low amount of fine material (34%). A mean TOC for coastal and estuarine sediments in the U.S. has been reported to be just under 2% (Long 1995). The benthic community at this station is clearly degraded, although the nature or cause of the alteration may be attributed to multiple factors (e.g., the grain size of the sediment, freshwater upwelling or discharge).

7.3 BIOACCUMULATION EFFECTS ASSESSMENT

Bioaccumulation of CoCs indicates their bioavailability from sediment (and/or water), plus their transfer through a food web. Only certain contaminants (primarily lipophilic organics) are known to biomagnify to substantially greater levels with transfer to higher levels in a food chain. Others may be transferred, but generally will not increase with each successive step up in trophic level.

The presence of CoCs in the tissues of organisms sampled represents two pathways of exposure and potential risk. The first is a risk to the organisms themselves from the possible interactions of the CoCs with their own biochemical processes. The second risk is from a dietary dosage to predatory species which may feed upon the organisms sampled (i.e., an exposure factor or route). To evaluate both these risks, tissue body burdens may be compared against benchmark (e.g., Maximum Acceptable Tissue Concentrations or MATCs) which are related to adverse impacts. In this risk assessment, the first pathway is evaluated by comparison of field-collected fish (*Fundulus*) with MATCs for fish, while the second pathway is assessed with RTV benchmarks for avian species.

7.3.1 Bioaccumulation Effects in Fish

Only marginal gross, pathological adverse effects were directly observed in fish collected in the study area. Out of the hundreds of mummichog collected, very few fish were observed to have slightly eroded fins. Because of the extremely low incidence, this observation will not be discussed further. Risk to the fish is examined essentially through comparison of body burdens with benchmark levels (i.e., MATCs).

The literature was reviewed for MATCs in fish tissue for all of the CoCs. Only six suitable MATCs were found **(Table 7-11)**. Most of the MATCs were associated with adverse reproductive success. These MATCs are compared with measured body burdens in mummichog. An attempt was made to use toxicity studies conducted with the species of concern used in this ERA, or with very closely related species. However, studies with these species could not be located. Differences between the test conditions and species studied and those that occur from the study area increase the uncertainty of applying these MATCs (see Section 9.0). However, these MATCs typically represent sensitive species and should therefore be protective of those species found in the study area.

Two of the four Upper Ferry Creek composite samples contained Cd and total PAH levels greater than the MATCs. These were the two samples (UF-03-FT and UF-04-FT) collected closest to the head of the creek. The sediment samples associated with, or adjacent to, areas

Table 7-11. Summary of MATCs used for fish tissue vs. concentrations observed in mummichog.

Analyte	Ranges in mummichog	MATC (µg/kg, ww)	Samples above MATC	Study Details	Reference
PCBs	b.d. — 590	200	RF-02-FT	MFO induction and reduced reproductive success in starry flounder eggs	Spies et al. 1985
DDT + DDE	b.d. — 15	220	NA	Concentration in eggs of winter flounder (based on LOEL of 2.2 with vertebral deformities in developing eggs and larvae)	Smith & Cole 1973
Cadmium	10 — 140	32	UF-03-FT UF-04-FT	Highest No Effect Concentration	Dillon & Gibson 1985
Mercury	10 — 20	3000	NA	NOEL for whole-body brook trout	McKim et al. 1976
Total PAHs [a]	b.d. — 546	140	UF-03-FT UF-04-FT	Concentration of total PAHs in the liver of flounder associated with normal gonadal development	Spies et al. 1985
PCDDs/ PCDFs [b]	0.52 — 1.9	50 in eggs 75 in parents	NA	No-effects thresholds for reproductive effects (mortality in embryos and young)	USEPA 1993

[a] Total PAHs include 9,10 dihydroanthracene, phenanthrene, anthracene, 1-methylphenanthrene, fluoranthene, pyrene, benzanthracene, chrysene/triphenylene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, benzo(*e*)pyrene, benzo(*a*)pyrene, perylene, benzo(*ghi*)pyrene

[b] Ranges in fish in ng/kg TEQs.

b.d. = below detection.

trawled for these two fish composites included some of the most contaminated samples observed during this round of sampling (e.g., SD21 and SD13) and were found to be classified as toxic by the bioassessments used for this ERA. HQs calculated for Cd (against MATCs) for samples UF-03-FT and UF-04-FT are 4.4 and 3.4, respectively. For PAHs, their HQs are 3.8 and 3.9, respectively.

One other exceedance of MATCs in mummichog tissues was observed. PCB levels in RF-02-FT, at 590 µg/kg, exceeded the MATC nearly threefold. Concentrations in the other reference area samples ranged from below detection to 80 µg/kg. No other analytes were elevated in this one sample. This is one of a few samples that experienced problems during the laboratory analytical procedure. Whether this value is an artifact of the analytical problems is unclear.

Higher trophic level, carnivorous fish species may also be at risk due to bioaccumulative compounds related to the site. To examine this issue, existing data for the white perch collected during previous field efforts were also evaluated. Because no dioxin or PAH data were available for these samples, analysis was limited to PCBs, DDTs, and Hg in white perch offal. Samples were collected from Selby Pond, near the boat club wetlands (Figure 2-1), and from Frash Pond. The maximum concentration of DDTs observed in tissue at Selby Pond, 350 µg/kg, and the maximum level of PCBs in a tissue sample from Frash Pond at 370 µg/kg (as Aroclor 1254) each exceeded their respective MATCs less than twofold (i.e., HQ of 1.75 and 1.85 for DDT and PCBs, respectively). Due to the lack of full analytical chemistry, the limited sampling locations, and tissues sampled, these data cannot be considered complete enough to

adequately address bioaccumulative, trophic transfer risk to fish species. Therefore, this endpoint will not be considered further.

7.3.2 Bioaccumulation Effects in Birds

Risk from dietary exposure to bioaccumulative CoCs for two predatory avian species which may feed upon the organisms residing within areas affected by the site was evaluated using a food-web model (discussed in Section 5). Media-specific levels of CoCs were used in Equation 5-5 to estimate total dietary intake of CoCs for the black-crowned night heron and red-winged blackbird. **Table 7-12 (a-e)** presents the data on contaminants in prey items used in the food-web model for each exposure media (i.e., water, sediment crabs, fish, insects) for each area sampled (i.e., Ferry Creek, boat club wetlands, and reference). The table also indicates whether the values used were 95% upper confidence limits, maximum observed concentrations, or cases when only a single value was available (according to the data evaluation approach outlined in Section 5). These exposure data were then compared with RTVs for avian species to assess the potential for adverse effects.

The literature was reviewed for RTVs for birds for all CoCs at the Raymark facility. These NOELs and LOELs were obtained from the primary literature, EPA review documents, and on-line database (IRIS). **Table 7-13** presents the RTVs used as benchmarks in the food-web model. These RTVs are expressed as daily doses of contaminants normalized to the body weight of the test species. Values were not available for all CoCs. NOELs were available for many, but not all, CoCs. For mercury, a LOEL was used with a one-half extrapolation factor (from EPA 1993) to arrive at a NOEL value. For all other LOEL-to-NOEL conversions, one-tenth was used as the conversion factor. One analysis of avian LOEL-to-NOEL extrapolation values found that half the ratios are less than a factor of 3 (US EPA unpubl.). Therefore the factor of one-tenth used here should be adequately conservative. Data are rarely available for the wildlife species of interest, and most often must be extrapolated from other species (e.g., chicken, mallard). Because of this, the same RTVs were used for both heron and blackbirds. The RTVs were used as reported by their original authors, with no inter-species conversion other than allometric scaling to the heron and blackbird.

The results of the food-web model for black-crowned night heron, expressed as Hazard Quotients (HQs), are presented for each area in **Tables 7-14 (a-c)**. The contribution of each exposure media to the heron diet is shown, with the resulting total dietary dose. This total contaminant dose in the diet was then compared with the RTVs listed in Table 7-13 to calculate HQs for each CoC. HQs for each CoC were then summed and expressed as a Hazard Index (HI) to estimate the risk from the total cumulative dietary exposure.

Because the prey organisms included in the food-web model (and sampled from the site) represent about 75% of the diet reported for heron, a second set of risk quotients (the "adjusted" HQ) was also calculated. For the adjusted HQ, it was assumed that the contamination of the remaining 25% of the reported diet (e.g. small mammals, frogs) is the same as in the sampled and analyzed portion. The resulting adjusted HQs were about 33% greater. This is a conservative calculation which accounts for the uncertainty regarding the contaminant concentrations in the unsampled items of the reported diet of heron.

The HQ results for heron indicate that RTVs were exceeded only by Cr, and Pb. For Cr, the boat club wetlands were the only site-related area for which the HQs exceeded 1 (the adjusted HQ=1.06). Sediment was the principle media contributing to this value. Incidental sediment ingestion was estimated to equal 5% of the heron's dietary requirement. No data were available on the toxicity of Cr^{+6}, nor for the assimilation efficiency of Cr. For this

Table 7-12a. Concentrations of CoCs used as inputs to the avian food web model for each exposure r

Insect Tissue Data used in the Avian Food Web Model

	Ferry Creek				Reference area			
Inorganics (mg/kg, ww)	ncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected
Arsenic	0.24	x	na		0.25			x
Cadmium	0.94	x	na		0.76	x	na	
Chromium	1.04	x	na		1.73	x	na	
Copper	28	x	na		29.69	x	na	
Lead	2.22	x	na		7.2	x	na	
Mercury	0.01			x	0.015			x
Nickel	0.9	x	na		0.73	x	na	
Silver	nr				nr			
Zinc	77.5	x	na		87.05	x	na	
2,3,7,8-TCDD (ng/kg, ww)	2.23	x	na		1.35	x	na	
PAHs (ug/kg, ww)								
Acenaphthene	10			x	10			x
Acenaphthylene	10			x	10			x
Anthracene	10			x	10			x
Benz(a)anthracene	50			x	50			x
Benzo(a)pyrene	50			x	50			x
Benzo(b)fluoranthene	50			x	50			x
Chrysene	50			x	50			x
Dibenz(a,h)anthracene	50			x	50			x
Fluoranthene	10			x	10			x
2-Methylnaphthalene	nr				nr			
Naphthalene	10			x	10			x
Phenanthrene	26	x	na		47	x	na	
Pyrene	10			x	10			x
DDTS (ug/kg,ww)	12			x	12			x
PCBs (ug/kg, ww)	160			x	140			x

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12b. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Fish Tissue Data used in the Avian Food Web Model

	Ferry Creek				Reference area			
Inorganics (mg/kg, ww)	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected
Arsenic	0.6		x		0.45	x		
Cadmium	0.08		x		0.018	x		
Chromium	1.6		x		2.2	x		
Copper	11.2		x		6.5	x		
Lead	6.3		x		0.64	x		
Mercury	0.014		x		0.016	x		
Nickel	0.74		x		0.45	x		
Silver	0.03		x		0.05	x		
Zinc	49.9		x		42.6	x		
2,3,7,8-TCDD (ng/kg, ww)	1.3		x		0.67	x		
PAHs (ug/kg, ww)								
Acenapnthene	5	x			2.5	x		x
Acenaphthylene	2.5	x		x	2.5	x		x
Anthracene	5	x			2.5	x		x
Benz(a)anthracene	23	x			2.5	x		x
Benzo(a)pyrene	46	x			5	x		
Benzo(b)fluoranthene	114	x			7	x		
Chrysene	62	x			2.5	x		x
Dibenz(a,h)anthracene	7	x			2.5	x		x
Fluoranthene	86	x			2.5	x		x
2-Methylnaphthalene	2.5	x		x	2.5	x		x
Naphthalene	6	x			2.5	x		x
Phenanthrene	55	x			2.5	x		x
Pyrene	62	x			2.5	x		x
DDTS (ug/kg,ww)	11.1		x		30	x		
PCBs (ug/kg, ww)	213.7		x		144C	x		

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12c. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Sediment Data used in the Avian Food Web Model

	Ferry Creek			Housatonic Boat Club Wetland			Reference		
Inorganics (mg/kg, ww)	ncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected
Arsenic	3.3		x		4.5		x		3.7		x	
Cadmium	1.9		x		0.67		x		0.55		x	
Chromium	66		x		140		x		121.3		x	
Copper	363.4		x		482		x		434.7	x		
Lead	250.5		x		122		x		42.1		x	
Mercury	0.19		x		0.4		x		0.38	x		
Nickel	30		x		18.5		x		14.4		x	
Silver	0.53		x		0.6		x		0.4		x	
Zinc	223.5		x		166.2		x		175.6		x	
2,3,7,8-TCDD (ng/kg, ww)	22		x		13.5		x		4.5		x	
PAHs (ug/kg)												
Acenaphthene	1794.5	x		x	825.75	x		x	192.4	x		x
Acenaphthylene	1794.5	x		x	825.75	x		x	192.4	x		x
Anthracene	1794.5	x		x	825.75	x		x	192.4	x		x
Benz(a)anthracene	1183.8		x		403.5		x		188.9		x	
Benzo(a)pyrene	1038.5		x		342.6		x		175.5		x	
Benzo(b)fluoranthene	1989.7		x		516.2		x		312.1		x	
Chrysene	1331.7		x		455.8		x		189.9	x		
Dibenz(a,h)anthracene	790.8		x		274.5		x		189.9		x	
Fluoranthene	2519.2		x		610.8		x		337		x	
Flourene	1794.5	x		x	825.75	x		x	192.4	x		x
2-Methylnaphthalene	1794.5	x		x	825.75	x		x	192.4	x		x
Naphthalene	1794.5	x		x	825.75	x		x	192.4	x		x
Phenanthrene	1087.2		x		263.3		x		189.9		x	
Pyrene	2018		x		541.8		x		268.8		x	
DDTS (ug/kg,ww)	7		x		6.5		x		3		x	
PCBs (ug/kg, ww)	625.8		x		274		x		135.9		x	

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12d. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Crab Data used in the Avian Food Web Model

Inorganics (mg/kg, ww)	Ferry Creek				Housatonic Boat Club Wetlanda				Reference a			
	ncentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected	ncentration	Maximum Value	95% UCL	Undetected
Arsenic	1.6	x			2.00	na	na	na	1.70	na	na	na
Cadmium	1.26	x			0.05	na	na	na	0.09	na	na	na
Chromium	2.32	x			2.29	na	na	na	3.73	na	na	na
Copper	72.2	x			102.72	na	na	na	52.65	na	na	na
Lead	15.8	x			52.49	na	na	na	3.66	na	na	na
Mercury	0.01	x		x	0.02	na	na	na	0.02	na	na	na
Nickel	3.3	x			2.58	na	na	na	2.75	na	na	na
Silver	nr				nr	na	na	na	nr	na	na	na
Zinc	27.4	x			27.14	na	na	na	23.49	na	na	na
2,3,7,8-TCDD (ng/kg, ww)	4.28	x			15.7	na	na	na	2.29	na	na	na
PAHs (ug/kg)												
Acenaphthene	25	x		x	25	x		x	25			x
Acenaphthylene	25	x		x	25	x		x	25			x
Anthracene	25	x		x	25	x		x	25			x
Benz(a)anthracene	20	x			5	x			25			x
Benzo(a)pyrene	30	x			7	x			6	na		na
Benzo(b)fluoranthene	33	x			12	x			9			
Chrysene	31	x			13	x			25			x
Dibenz(a,h)anthracene	10	x			25	x		x	25			x
Fluoranthene	53	x			25	x		x	25			x
Flourene	25	x			25	x		x	25			x
2-Methylnaphthalene	nr				nr				nr	na		na
Naphthalene	6	x			25	x		x	5	na		na
Phenanthrene	16	x			25	x		x	25			x
Pyrene	54	x			25	x		x	25			x
DDTS (ug/kg,ww)	5.5	X		X					3.5			x
PCBs (ug/kg, ww) b	170	X			1560				60	na		na

Concentrations where the value was undetected are 1/2 the detection lim a — Only one sample collected from this area.

nr: not reported b — Value is for total PCBs as determined by EPA.

na: not applicable because only one sample was collected from this area

Table 7-12e. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Surface Water Data used in the Avian Food Web Model

	Ferry Creek				Housatonic Boat Club Wetland				Reference			
Inorganics (µg/L)	ncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected
Arsenic	21.6		x		16.2	x			4.8	x		
Cadmium	1.2	x		x	2.3	x			0.7	x		x
Chromium	12.4		x		59.2	x			15.9	x		
Copper	121	x			138	x			17.9	x		x
Lead	13.7		x		37.2	x			3.3	x		
Mercury	0.55		x		3.5	x			6	x		
Nickel	11.7	x			1.8	x		x	1.8	x		x
Silver	1.7	x		x	1.7	x		x	1.7	x		x
Zinc	127	x			15.5	x		x	r			
2,3,7,8-TCDD (ng/L)	na				na				na			
PAHs (ug/L)												
Acenaphthene	5	x		x	5	x		x	5	x		x
Acenaphthylene	5	x		x	5	x		x	5	x		x
Anthracene	5	x		x	5	x		x	5	x		x
Benz(a)anthracene	5	x		x	5	x		x	5	x		x
Benzo(a)pyrene	5	x		x	5	x		x	5	x		x
Benzo(b)fluoranthene	5	x		x	5	x		x	5	x		x
Chrysene	5	x		x	5	x		x	5	x		x
Dibenz(a,h)anthracene	5	x		x	5	x		x	5	x		x
Fluoranthene	5	x		x	5	x		x	5	x		x
Flourene	5	x		x	5	x		x	5	x		x
2-Methylnaphthalene	5	x		x	5	x		x	5	x		x
Naphthalene	5	x		x	5	x		x	5	x		x
Phenanthrene	5	x		x	5	x		x	5	x		x
Pyrene	5	x		x	5	x		x	5	x		x
DDTS (ug/L)	0.104		x		0.15	x		x	0.15	x		x
PCBs (ug/L)	2.1		x		2.25	x		x	2.25	x		x

Concentrations where the value was undetected are 1/2 the detection limit

r: all data were rejected

na: not analyzed

Table 7-13. RTVs for use in the avian food web model and their sources.

Contaminant of Concern	Compound Tested	Test Species	Body Weight (kg)	Condition Evaluated [a]	RTV (mg/kg Bw/day)	Endpoint	Extrapolation Factor [b]	Source	Allometrically scaled species-specific NOEL BCNH (mg/kg Bw/day)	Allometrically scaled species-specific NOEL RWBB (mg/kg Bw/day)
arsenic	sodium arsenite	mallard	1	M	5.135	Chronic NOEL	NA	USFWS 1964	5.35	13.6
cadmium	cadmium chloride	mallard	1.153	R	1.45	Chronic NOEL bounded	NA	White and Finley 1978	1.58	4.02
chromium+3	CrK(SO4)2	black duck	1.25	R	1	Chronic NOEL	NA	Hasetine et al., unpub.	1.12	2.85
copper	copper oxide	chicken	0.534	G,M	28.13	Chronic NOEL bounded	NA	Mehring et al. 1960	23.8	60.3
lead	metallic	American kestrel	0.13	R	2.05			Paltee 1984	1.08	2.75
mercury		mallard	1	R	0.064	LOEL unbounded	1/2	Heinz et al. 1979	0.03	0.08
nickel	nickel sulphate	mallard	0.782	M,G	77.4	Chronic NOEL bounded	NA	Cain and Pafford 1981	74.3	188.5
silver	silver nitrate, chloride, and thiosulfate	chickens	0.4	G	12.5	Subchronic NOEL	NA	Hill and Matrone 1970	9.6	24.4
zinc	zinc carbonate	chicken	1.9	M	11.3	Chronic NOEL	NA	Gasaway and Buss 1972	14.6	37.0
Dioxin TEQs	2,3,7,8-TCDD	ringed-neck pheasants	0.121	R	0.000014	Chronic NOEL bounded	NA	Nocsek et al. 1992	0.000007	0.000018
Naphthalene	TPH	mallard	1.3	M	338	Chronic LOEL	1/10	Patton and Dieter 1980	38.4	97.5
Phenanthrene	TPH	mallard	1.3	M	338	Chronic LOEL	1/10	Patton and Dieter 1980	38.4	97.5
DDTS		brown pelican	3.5	R	0.028	Chronic LOEL	1/10	EPA 1993	0.004	0.011
PCBs		pheasant	1	R	1.8	Chronic LOEL	1/10	EPA 1993	0.19	0.48

a— M: mortality R: reproduction G: growth

b — EPA, 1993: LOEL to NOEL factor of two, rather than ten, was used for Hg because the LOEL appeared to be near the threshold for dietary effects.

assessment, an RTV for Cr^{+3} and 85% assimilation was assumed. Also, speciation of Cr was not valuated; therefore, total Cr concentrations in sediment and tissues were used. The adjusted HQ for Cr also exceeded 1 for the reference area (HQ=1.32). Sediment accounted for about 75% of the estimated ingested concentration of Cr for this area.

Total ingestion of Pb calculated for both the Ferry Creek and boat club wetland areas resulted in HQs exceeding 1. The unadjusted HQs for Pb were 2.59 and 2.33 for the Ferry Creek and boat club wetland areas, respectively; whereas the adjusted HQs were 3.45 and 3.11, respectively. Fish consumption accounted for 85% of the total estimated amount of Pb ingested in the wetland area, but only about one-third of the total for the Ferry Creek area. Estimated incidental ingestion of sediment in the Ferry Creek area accounted for most (60%) of the total modeled concentration of Pb ingested.

HQs for DDTs and PCBs also exceeded 1, but only at the reference area. The adjusted HQs for Milford Point for DDTs and PCBs were 1.21 and 1.33, respectively. The fish represented nearly the entire exposure for these CoCs. For this assessment, 85% assimilation was assumed, maximum values were used, and undetected Aroclors were added to the sum of all PCBs at one-half their detection level. Also, the PCB values were suspect due to laboratory analytical concerns. The value used for total PCBs in the model was 1,440 µg/kg (from sample RF-02-FT), when in fact the highest actual detected value was 590 µg/kg as Aroclor 1260 (430 µg/kg in a lab duplicate), and the second highest detected value was only 80 µg/kg as Aroclor 1260. Aroclor 1260 was the only Aroclor detected in any fish samples; however, Aroclor 1268, a CoC, was not included in the analysis. It is also unlikely that heron feed exclusively in an area as small as that represented by the area of the fish-tissue composite collected for this assessment. These factors lead to a conservative, possible overestimate of risk due to PCBs. It is unlikely that there would be any impact to heron from exposure to these CoCs in the Milford Point wetland area.

This assessment estimated the risk associated with each CoC individually. Certain combinations of contaminants are known to have synergistic or antagonistic impacts in concert. In particular, the chlorinated compounds—DDTs, PCBs, and TCDD TEQs—are known to have certain interactions. The sum of HQs (the Hazard Index, or HI) for these chlorinated compounds therefore carries some uncertainty and may overestimate their potential cumulative impact. For instance, not all PCB congeners interfere with biological systems in a similar manner. However, a summation of these compounds allows some estimate of potential impact. For the Ferry Creek area, the HI was 0.66, and the adjusted HI was 0.85. Fish and crabs contributed the major proportion of HQs for DDTs and PCBs, while fish, crab, and sediment contributed equally to the TCDD TEQ HQ. Given that contamination of Ferry Creek is moderately widespread, and that these CoCs have similar environmental behavior (e.g., biomagnification, extreme persistence) and biological impacts (e.g., reproductive impairment), it is possible that these CoCs in combination might have cumulative impacts. It should also be noted that PCB congeneranalysis was not performed; therefore, impacts from particular congeners cannot be estimated.

Table 7-14a. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Ferry Creek

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i mg/kg Bw /day	RfV mg/kg Bw /day	Hazard Quotient	Adjusted HQ (b)
Inorganics										
arsenic	0.08	0.058	0.0005	0.020	0.00108	0.1	0.2	5.35	0.03	0.04
cadmium	0.01	0.045	0.0019	0.011	0.00006	0.06	0.1	1.58	0.04	0.06
chromium (+3)	0.21	0.084	0.0021	0.396	0.00062	0.6	0.7	1.12	0.60	0.79
copper	1.49	2.509	0.0560	2.180	0.00605	4.1	4.7	23.79	0.20	0.34
lead	0.84	0.569	0.0044	1.503	0.000685	2.5	2.8	1.08	2.59	3.45
mercury	0.00	0.000	0.0000	0.001	0.0000275	0.003	0.003	0.0334	0.10	0.13
nickel	0.10	0.119	0.0018	0.180	0.000585	0.34	0.4	74.3	0.01	0.01
silver	0.00	nr	nr	0.003	0.000085	0.01	0.007	9.60	0.0007	0.0010
zinc	6.64	0.986	0.1550	1.341	0.00635	7.8	8.8	14.6	0.60	0.80
TCDD TEQs (a)	0.17	0.154	0.0045	0.13	nr	0.39	0.4	7.22	0.06	0.08
Naphthalene	0.0008	0.00022	0.000020	0.011	0.00025	0.01	0.012	38.4	0.0003	0.0004
Phenanthrene	0.0073	0.00058	0.000052	0.0065	0.00025	0.01	0.014	38.4	0.0004	0.0005
DDTS	0.0015	0.00020	0.000024	0.0000	0.0000052	0.0015	0.0017	0.0044	0.38	0.51
PCBs	0.0284	0.00612	0.000320	0.0038	0.000105	0.03	0.037	0.188	0.20	0.26
								Hazard Inde =	4.80	6.48

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14b. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Housatonic Boat Club Wetlands

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i ng/kg Bw-da	ng/kg Bw-day	RTV	Hazard Quotient	Adjusted HQ (b)
Inorganics											
arsenic	nc	0.072	nc	0.027	0.00081	0.1	0.1		5.35	0.02	0.02
cadmium	nc	0.002	nc	0.004	0.000115	0.01	0.01		1.58	0.004	0.005
chromium (+3)	nc	0.082	nc	0.840	0.00296	0.8	0.9		1.12	0.79	1.06
copper	nc	3.698	nc	2.892	0.0069	4.3	4.9		23.79	0.20	0.36
lead	nc	1.889	nc	0.732	0.00186	2.2	2.5		1.08	2.33	3.11
mercury	nc	0.001	nc	0.002	0.000175	0.003	0.003		0.0334	0.09	0.12
nickel	nc	0.093	nc	0.111	0.00009	0.17	0.2		74.3	0.0026	0.0035
silver	nc	nr	nc	0.004	0.000085	0.003	0.004		9.60	0.0004	0.0005
zinc	nc	0.977	nc	0.997	0.000775	1.7	1.9		14.6	0.13	0.17
TCDD TEQs (a)	nc	0.57	nc	0.081	nr	0.55	0.6		7.22	0.09	0.11
Naphthalene	nc	0.00009	nc	0.0050	0.00025	0.005	0.005		38.4	0.0001	0.0002
Phenanthrene	nc	0.00009	nc	0.0016	0.00025	0.002	0.002		38.4	0.00005	0.00006
DDTS	nc	0	nc	0.000039	0.0000075	0.00004	0.00004		0.0044	0.01	0.01
PCBs	nc	0.056	nc	0.001644	0.0001125	0.05	0.06		0.188	0.30	0.40
								Hazard Inde =		3.97	5.37

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14c. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Milford Point Reference Area

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i mg/kg Bw /day	RTV mg/kg Bw /day	Hazard Quotient	Adjusted HQ (b)
arsenic	0.06384	0.061	0.0005	0.022	0.00024	0.1257952	0.14	5.35	0.03	0.04
cadmium	0.002394	0.003	0.00152	0.003	0.000035	0.0088633	0.01	1.58	0.01	0.01
chromium (+3)	0.2926	0.134	0.00346	0.728	0.000795	0.9850274	1.12	1.12	0.99	1.32
copper	0.9044	1.895	0.05938	2.608	0.000895	3.5543086	4.0	23.79	0.17	0.29
lead	0.08512	0.132	0.0144	0.253	0.000165	0.4115117	0.47	1.08	0.43	0.57
mercury	0.002128	0.001	0.00003	0.002	0.0003	0.0047277	0.005	0.0334	0.16	0.21
nickel	0.05985	0.099	0.00156	0.086	0.00009	0.2097671	0.24	74.3	0.003	0.004
silver	0.00665	nr	nr	0.002	0.000085	0.0077648	0.01	9.60	0.001	0.001
zinc	5.6924	0.845	0.1741	1.054	r	6.6005302	7.5	14.6	0.51	0.68
TCDD TEQs (a)	0.08911	0.082	0.00276	0.027	nr	0.1711135	0.19	7.22	0.03	0.04
Naphthalene	0.0003325	0.00018	0.000020	0.0012	0.00025	0.0016464	0.002	38.4	0.00005	0.00006
Phenanthrene	0.0003325	0.00009	0.000094	0.0011	0.00025	0.00162	0.002	38.4	0.00005	0.00006
DDTS	0.00399	0.00013	0.000024	0.000018	0.0000075	0.0035407	0.0040	0.0044	0.91	1.21
PCBs	0.19152	0.002	0.00028	0.00082	0.00011	0.17	0.19	0.188	1.00	1.33
								Hazard Inde =	4.21	5.68

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of 25% unsampled.

nr: analyte not reported in this media

r: concentration data rejected

Results of the HQ calculations for the red-winged black bird for the Upper Ferry Creek and reference areas are presented in **Table 7-15**. For this assessment, it was assumed that the entire food diet was insects. Red-winged blackbirds feed their nestlings primarily insects. The total dietary dosage also included water as an exposure route. Assimilation efficiencies of CoCs used were the same as those for the heron: 65% for copper, and 85% for all other CoCs. A home range factor of 90% was incorporated, as well.

The results of the food-web model for blackbirds indicate no HQs greater than 1. The modeled ingestion of chlorinated compounds (DDTs, PCBs, and TCDD TEQs) approaches only one-third of the benchmarks (i.e., HI<0.33).

Table 7-15 Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the Red-winged Black Bird.

Ferry Creek

Contaminant of Concern	Insects mg/day, ww (0.023kg/day)	Water mg/day, ww (0.01L/day)	Total [a] Assimilated mg/day	Total [b] mg/kg Bw /day	RTV mg/kg Bw /day	Hazard Quotient
Inorganics						
arsenic	0.0050	0.00022	0.0044	0.07	13.6	0.005
cadmium	0.019	0.00012	0.0165	0.28	4.02	0.069
chromium (+3)	0.022	0.00012	0.0184	0.31	2.85	0.11
copper	0.58	0.0012	0.38	6.29	60.3	0.104
lead	0.046	0.00014	0.0392	0.65	2.75	0.24
mercury	0.00021	0.000055	0.0002	0.003	0.085	0.04
nickel	0.019	0.00012	0.0159	0.27	188.5	0.0014
silver	nr	0.000017	0.0000	0.0002	24.4	0.000010
zinc	1.60	0.013	1.3647	22.74	37.0	0.61
TCDD TEQs (c)	0.05	nr	0.0392	0.65	18.3	0.036
Naphthalene	0.00021	0.000050	0.0002	0.0036	97.5	0.000037
Phenanthrene	0.00054	0.000050	0.0005	0.01	97.5	0.000085
DDTS	0.00025	0.000010	0.0002	0.0035	0.011	0.31
PCBs	0.0033	0.000021	0.0028	0.05	0.48	0.099
					Hazard Index =	1.63

Milford Point Reference Area

Contaminant of Concern	Insects mg/day, ww (0.023kg/day)	Water mg/day, ww (0.01L/day)	Total Assimilated mg/day	Total mg/kg BW/day	RTV mg/kg Bw-day	Hazard Quotient
Inorganics						
arsenic	0.0052	0.000048	0.0044	0.07	13.6	0.01
cadmium	0.016	0.00007	0.0134	0.22	4.02	0.06
chromium (+3)	0.036	0.00016	0.0306	0.51	2.85	0.18
copper	0.61	0.00179	0.40	6.66	60.3	0.11
lead	0.15	0.00033	0.1267	2.11	2.75	0.77
mercury	0.00031	0.00006	0.0003	0.01	0.085	0.06
nickel	0.016	0.00018	0.0137	0.23	188.5	0.0012
silver	nr	0.00017	0.0000	0.00	24.4	0.00001
zinc	1.80	r	1.5316	25.53	37.0	0.69
TCDD TEQs (c)	0.029	nr	0.0243	0.40	18.3	0.02
Naphthalene	0.00021	0.00005	0.0002	0.004	97.5	0.00004
Phenanthrene	0.00097	0.00005	0.0009	0.01	97.5	0.0001
DDTS	0.00025	0.000015	0.0002	0.004	0.011	0.32
PCBs	0.0029	0.000225	0.0025	0.04	0.48	0.09
					Hazard Index =	2.30

a — Adjusted for bioavailability factor.

b — Adjusted for 90% home range factor.

c — 2,3,7,8-TCDD TEQs in ng/kg, ww

nr: analyte not reported in this media

r: concentration data rejected